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ON THE

HISTORY AND ART
OF
WARMING AND VENTILATING
ROOMS AND BUILDINGS

BY

OPEN FIRES, HYPOCAUSTS, GERMAN, DUTCH, RUSSIAN, AND
SWEDISH STOVES, STEAM, HOT WATER,
HEATED AIR, HEAT OF ANIMALS, AND OTHER METHODS;

WITH

NOTICES OF THE PROGRESS
OF
PERSONAL AND FIRESIDE COMFORT,
AND OF THE
MANAGEMENT OF FUEL.

ILLUSTRATED BY TWO HUNDRED AND FORTY FIGURES
OF APPARATUS.

BY

WALTER BERNAN,

CIVIL ENGINEER.

Meikleham, Robert

VOL. II.

LONDON:
GEORGE BELL, FLEET STREET.
MDCCCXLV.

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LONDON:
WILLIAM STEVENS, PRINTER, BELL YARD
TEMPLE BAR.

THE ART OF WARMING AND VENTILATING BUILDINGS.

ESSAY IX.

The Cardinal Polignac is known as one of the most classic of modern Latin poets; and his biographers, in their admiration of his nervous versification, profound reasoning, and benevolence of sentiment, place him almost above the great Roman author whose opinions he combats and overthrows.

A small work in a different style of composition, and on a somewhat unpoetical subject, that he composed in 1713, also possesses superlative merit. In this useful treatise, the cleric prince observes, that persons who value a machine only from the apparently great effort of genius required to invent it, from the complexity of its parts, the difficulties encountered, and money spent in bringing it into notice, will find little to please their romantic taste in his performance. But those of a more correct judgment, who can see worth in a contrivance notwithstanding its simplicity of construction and easiness of execution, will, perhaps, prefer his apparatus to more ostentatious productions; and what, for instance, can be more pleasant, useful, economical, and necessary, than to know how to make a fire speedily, and make

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it burn vividly without the aid of bellows; to heat a capacious room with a small fire, and at the same time breathe an air fresh and pure, as well as healthily warm? In *Le Mécanique à Feu,* he shows how these, and other desirable comforts, may be obtained by means of a very simple contrivance.

There is a large class of persons, he thinks, who will undervalue his labours from an apprehension that warm apartments are unfriendly to health; and the cardinal admits that very hot confined air often found in rooms heated by some kinds of stoves, and even by open fires, must be prejudicial in many cases to those who breathe it. But rooms which are always supplied with an unremitting succession of fresh air, cannot be liable to this objection. Those who urge the danger of passing suddenly from a warm room into the cold air, show by their own practice their objection is groundless, for their fears do not prevent them producing and keeping up during the night, with blankets, soft beds, and curtains, as high a temperature as they can around their persons. Nor are they afraid every morning of their lives, even during the most inclement weather, to rise from the warm bed in which they have been reposing for many hours, and dress themselves in cold clothes, in a room without a fire. Neither does their affected apprehension of this danger hinder them sitting during the day before a large fire, and wrapping themselves up in the warmest clothing. Our own experience, as well as the practice of our neighbours, should be sufficient to convince us that we are never better able to withstand the cold weather, than when we emerge from a warm room with every part of our body equally saturated, as it were, with heat. The practice, continues the cardinal, of the Danes, Germans, and other northern people, who live in climates colder than that of France, proves that rooms warmed to a high degree by stoves do not produce disease more than rooms warmed by open fires. On the contrary, these people, and we ourselves, fly to warm apartments as a specific, or as a mitigator of many disorders produced by the cold. It is not the warmth of a room, but its inequality of temperature and want of ventilation, that is the origin of numerous maladies: we cannot, therefore, be too cautious of living in those in which this dangerous imparity of heat and motionless air exists, nor remain too long in rooms into which temperately warm fresh air is constantly flowing and diffused. The natives of countries where the rooms are warmed by stoves (or enclosed fireplaces), and the art of distributing heat is well understood, complain, when they come into France, that when a man is very cold, he must set himself down before the open fire, to see the wood burn at some distance before him, or if he approach nearer, he must stand or sit double with his head and feet quite in the chimney, and scorch his eyes, face, and legs, and at the same time freeze in other parts. So that, in truth, he warms himself to augment his grievance.

All this suffering and inconvenience, the cardinal demonstrates, was produced in his and by-gone times by house-raisers feeling they had done their duty when they had provided hearths, without duly considering that the end sought by burning the fuel in a chimney was to warm the rooms and the persons in them. These builders never seem to have reflected on the fact, that we receive the heat emanating from burning bodies in more ways than one. It may come directly from the fire or hot body, and then we are warmed by what is called *radiant* heat; and it may be thrown off from a body on which it has fallen, and our sensation is produced by *reflected* heat; or it may be conducted through a solid body, as when fuel is burned in a stove, and the hot surface heats the air which surrounds and warms us. Fuel burned on a common hearth, enclosed on three sides, does not warm the room by conducted heat. It emits but a very small part of its radiant heat into the apartment, and nearly all the reflected heat is retained in the hearth recess. In the cardinal's fireplace, not only a much greater proportion of radiant and reflected heat were applied to their proper purpose, but the air was heated by conduction also.

The jambs of the hearth recess were always built parallel, and at right angles to the back. The width of the opening varied from 3 feet 6 inches to 8 feet, and seldom had a less depth than 2 feet 3 inches, and was from 4 to 7 feet high. From the position of the jambs and their depth, it will be apparent that they could reflect little heat from their plastered surface; more of the heat was reflected from the back; but from the position of the fuel, a large proportion of the incident rays made a very acute angle with the back, and consequently was reflected into the chimney throat. Of the radiant heat, only that small portion which emanated in a direction little removed from the horizontal, had any effect in warming the room. A slight inclination of the heating rays at their focus carried them over the heads of those sitting round the fire, and they fell on the wall at too great a height to produce any effect that could be appreciated by the company. Rounding the angles of these deep parallel jambs, and lining them with plates of iron and brass to give them a neater appearance, slightly mended the faulty primitive construction.

The geometry of optics teaches us, says the cardinal, that all the rays proceeding from the focus of a parabola, and striking on its sides, are reflected in a direction parallel to its axis. If, therefore, the length of the wood to be burned be that of half a log or billet, which at Paris is about 22 inches, this may be taken as the proper width for the back of the fireplace. Points at this distance may be made the foci of two semi-parabolas, and the line that connects their vertices will form that of the back, and the outer extremity of each jamb will be a point in the curve. A hearth recess having this horizontal profile, its back and parabolic jambs covered with iron or brass plates, the soffite of the mantel made horizontal, and the smoke flue contracted to a size of 10 or 12 inches square, "will, I affirm," says the cardinal after a very satisfactory mathematical demonstration, "emit and reflect incomparably more heat than any of the ordinary fireplaces."

The "soufflet" or blower in the hearth has already been noticed as a common contrivance for kindling a fire,* and the cardinal adopted it not only for this purpose, but as a way of keeping up a constant vivid combustion in the fuel without the personal trouble of applying bellows.

In the centre of the hearth recess, and at a distance of 10 or 12 inches from the bottom plate or focus on which the fuel was burned, a channel or *cold air-duct*, from 4 to 6 inches square, was made under the hearth, and carried outwards until it met the open air. Its opening on the hearth was closed with a metal frame forming an aperture 3 inches long and 2½ inches wide. A trap door or valve was hinged on this frame, to lift upwards. On the upper side of the valve was a button that could be laid hold of by the tongs, and a little bolt beneath, which was drawn back or closed with the button that moved it. Two thin sector-shaped slips of iron formed the sides of the valve, and guided the current of wind that came through the channel directly upon the fire when the valve was lifted up. Two springs, fastened under the frame, pressed against the sector pieces, and kept the valve open at any angle at which it was set.

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* Mechanism of Fire, p. 5.

These were the only alterations recommended where it was not desirable to touch the mantel or any thing above it, or where the expense of a more perfect improvement could not be afforded.*

In his meritorious treatise, the cardinal delineates several complex varieties of his fireplace, in all of which, in addition to the parabolic jambs and soufflet that have been described, he introduces a hollow back, or jambs, or hearth, and mantel with valves to regulate the admission of the heated air into the apartment.

An aperture from 8 to 12 inches square was made in the external wall, and on a level with the floor of the room to be heated, or lower where it was practicable. An air channel was carried from this aperture to the hearth recess. The back of the fireplace was formed of a hollow case, like that in the Louvre chimney, but divided either in its width or height into three or more channels;—the first of which communicated at one end with the air-duct, and the other end with the second channel; and the second channel communicated with the third, and so on, if there was a greater number; and the last of the series opened into the room. In the air channel there was a valve resembling Papin's four-way cock, formed in the following manner:—A small cylinder, *x*, revolved within another which was fixed, and about 12 inches diameter and 9 inches high. The revolving cylinder had two apertures, *o o*, each 6 inches wide and about 7½ inches high. The fixed cylinder had three apertures, each about 6 inches wide and 8 inches high. The axis of the revolving cylinder went through the cover of the fixed cylinder, and had a small lever or needle fixed to it, with which the cylinder was turned by the finger into certain positions marked on a small dial. When the apertures *o o* in the revolving cylinder coincided with the apertures *u u* in the fixed cylinder, as shown in Fig. XLV., the external air from the channel was admitted into the caliducts in the chimney back, and by turning the revolving cylinder into another position the cold air was excluded from the caliducts and admitted directly into the apartment; the cylinder could also be placed to shut off the cold air both from the caliducts and from the room.

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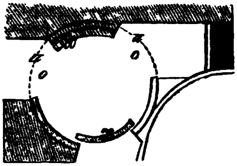
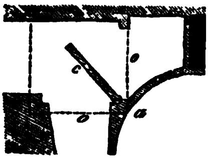
* Where this air-duct cannot be carried beneath the floor, or brought from an external wall, a small *vertical canal* or air-duct may be formed *in* the wall, or in the *smoke flue*, commencing a little below the level of the opening into the caliducts, and communicating with them, and carried up to any convenient height for making an opening into it from the external air. The air will then fall downwards in this air-duct, and circulate in the caliducts, and be emitted warmed into the room.—Mechanism of Fire, p. 71.

FIG. XLV.



A second device for the same purpose, Fig. XLVI., is somewhat more simple. Two attached frames, *i i*, each 5 inches by 8 inches, with an opening, *o o*, in each, were fitted into the cold air channel where it joined the first caliduct. A valve, *c*, moved on the axis *a*, which went through the cover, and had a needle attached to it by which the valve was moved by the finger to close or open the warm or cold air apertures *o o*, or to shut both, which will be understood from the figure.

FIG. XLVI.



In *Le Mécanique à Feu* the cardinal describes one arrangement of his fireplace with the caliducts or meanders perpendicular, as in Fig. XLVII.; another as having them placed in a horizontal position, as in

Fig. XLVIII. A third variety had the hearth made hollow, as in the Louvre fireplace, but divided into a series of square tubes or caliducts, through which the air flowed, and was heated as shown in Fig. XLVIII. In others, the mantel also was formed hollow; to receive and still further heat the air conducted into it from the caliducts in the back and hearth. The cold air entering at *a* is emitted at *x*; *c* is the hearth; *m*, the smoke flue; *d*, *s*, *i*, the caliducts —the arrows indicate the direction of the air.

FIG. XLVII.

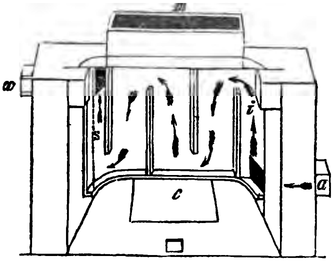
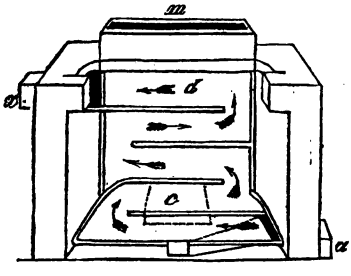


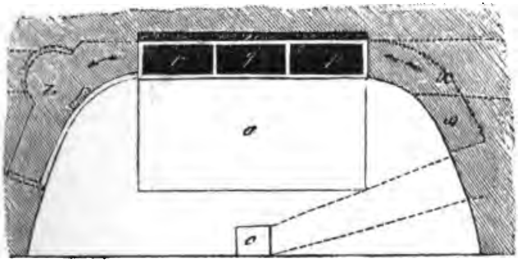
FIG. XLVIII.



Another combination requires a more detailed notice. It has been, *par excellence,* called the Polignac fireplace, and its display of ingenious adaptation of means to an end, well entitles it to this distinguished appellation.

Fig. XLIX. is an horizontal section of the fireplace. Fig. L. a vertical section, and Fig. LI. an elevation of the back.* The same letter in the three figures marks the same part.

FIG. XLIX.



The hollow metal case, forming the back of the chimney, is partitioned into three or more channels or caliducts, *p*, *q*, *r*, each 4 inches wide, and 6¾ inches broad, and placed about an inch from the back wall of the hearth-recess, with its lower edge, *m*, about 2 inches above the surface of the iron bottom plate, or hearth, *a*. The jambs, *w*, lined with iron or brass plates, are formed in a parabolic curve, and solid at the back. The channel *x*, conducting the external air into the caliducts, is 9 inches on the side; and the blower or soufflet, *c*, is of the size described in a previous page, but instead of being supplied with air from the outside by a separate channel, the air is derived from the channel z. The air valve, *x*, described in page 7, is placed at the junction of the cold air channel with the caliducts; and the aperture, z, through which the warmed air enters the room, is fitted with a sliding valve, to close the warm air aperture.

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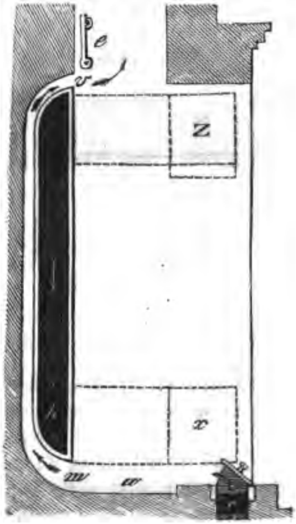
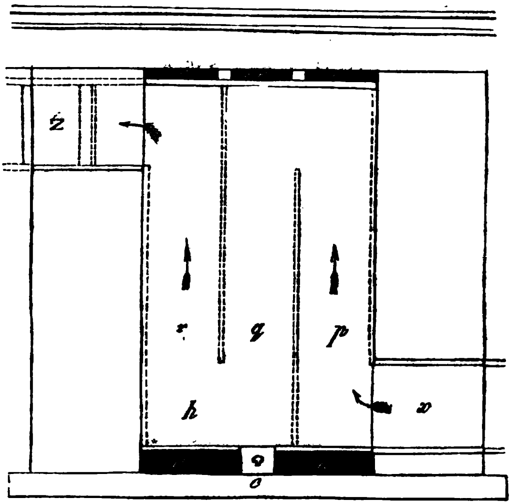
* Fires Improved, p. 105.

FIG. L.



The operation of this apparatus is very simple: the wood being laid on the hearth, the bavin lighted, and the valve of the soufflet, *c*, lifted up, the billets are speedily blown into a sparkling fire; the smoke and flame rise into the space, *n*, between the back, *p q r*, and wall of the hearth recess, and, after imparting their heat to the iron back of the caliducts, thence escape into the flue; while the other face towards the room, is also rapidly heated by the contact of the flame and smoke. The valve, *o*, being adjusted, to admit the external air into the first caliduct, it flows thence through the second and third, receiving fresh accessions of heat in its progress, until it escapes at z, considerably raised in temperature, and speedily diffuses an agreeable warmth throughout the apartment.

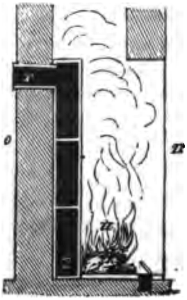
FIG. LI.



This arrangement was deservedly recommended by the cardinal as the best of the series described in his treatise; and he observes, that although the air does not take so long a course through the caliducts in this as in the other combinations; yet it is as quickly warmed, for the smoke and flame which pass behind the caliducts, act upon them as energetically as the flame does on the other side, and from both surfaces being thus heated, as much air is raised to the same degree, in two moments as would be in four, were the heat derived from one side only. It is obvious that if the cold air was admitted under the hearth, and the jambs lined with iron or brass plates, although the fireplace would be a little more complex, its effect would be augmented. And the whole arrangement, continues the cardinal, is so simple, so convenient, and easy of execution, that it is best adapted for general use, and "I myself at this moment apply it to very good purpose."

Fireplaces designed for large societies or companies, may be erected in the middle of the chamber, and two may be set back to back, with one series of caliducts for both, so that the air will be heated, whether the fire be made in one or in both. And on the same principle, if two hearth recesses in a private house were placed back to back in the division wall, one of these double fireplaces might be placed in the recess, with an opening from the caliducts into each room; and by making a fire in one, or in the other, as might be wanted, the heated air could be introduced into the room in which there was no fire, and warmed more comfortably, even than the apartment in which the fuel was burning.

FIG. LII.



If the rooms adjoin, and their hearth recesses are not placed near each other, and it is found inconvenient to fix a fireplace in each, nothing is more easy than to warm both apartments by one apparatus. All that is required being to insert a pipe, *x*, Fig. LII. connected with the caliducts through the wall, *o*, and the hot air will flow into the room in which there is no fire. It is obvious that a room in a floor above could be effectually heated and ventilated by carrying a pipe from the caliducts upwards through the ceiling; and that a room on a floor beneath could be ventilated by the same apparatus, as will be shown in detail in a following essay.*

The advantages of the Polignac fireplace over those on the common construction are very great. The external air, in passing through the caliducts, being raised to a temperate heat, and spreading itself throughout the chamber, a person in the coldest weather is surrounded with warm air, and heated, without going near the fire, on all sides at once; while from the construction of the hearth, he enjoys the radiant heat in greater perfection than in the common chimneys. The large body of air constantly flowing *into* the room from the caliducts, prevents all *chink winds* or dangerous disease-bringing currents; and as there is as much impure air withdrawn, as there is fresh warm air admitted, an unceasing salutary ventilation goes on, from the time the fire is lighted until it is extinguished; so that a person may always remain in a room thus warmed, and breathe as pure an air as if he were in the fields.

From the fear and danger of cold and draughts, the air in sick-rooms is seldom changed so often as is necessary; and the breath and exhalations thus confined are often as fatal to the attendants as the disease is to the patient. The continual admission of pure air warmed in one of these fireplaces, always keeps the sick-room ventilated, and the patient from breathing a pestilential atmosphere, that *must* aggravate whatever disease he is labouring under, if it does not itself generate a more atal malady. While, from the genial warmth that is maintained in all parts of the room, it is not necessary for the invalid to be loaded and choked with blankets and curtains, as is usually done almost to suffocation—nor is he himself, during the inclement season, afraid to stir even in bed, lest he catch cold.

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* The fireplaces were described in the Memoirs of the French Academy of Sciences for 1720; engravings of the apparatus are given in its collection of Machines Approuvés, tom. iv. p. 11. They differ nothing from the figures in "La Mécanique du Feu."

By fixing a flexible tube to the aperture at which the air enters the room, from the caliducts, it may be conveyed into a bed between the sheets, and made to fall on any part of the body of a person reposing, and warm it in the gentlest manner imaginable: a contrivance that might be of great advantage to invalids who require attendants to warm their linen without intermission; and also to those persons who may not be unwell, but who yet can get no warmth in bed at night, during cold weather. It need scarcely be added that the use of these chimneys is attended with another comfort, as much desired by the healthy as the sick—of clothes, furniture, and other things being preserved in all weather, free from damp and mouldiness. In the course of his experience the cardinal found, that his fireplace was a perfect specific against the annoyance of smoke in rooms, which destroyed the lungs of those who breathed it, and smutched the finishings of the walls, furniture, and every thing in the apartment, "and particularly the lace, linen, skin, and eyes of the ladies."

All the fireplaces described by the cardinal were adapted for burning wood only. In 1715 Doctor Desaguliers made a translation into English of the French treatise; and in an appendix gave directions, with figures, how to construct the apparatus to burn sea-coal. In conjunction with Du Bois, an architect, the doctor began to manufacture the fireplaces, and from his declining to expatiate on the benefits to be reaped from their use, because "of the evidence of so many in London that were erected under his directions," the partners seem to have driven a thriving trade. In their practice they discarded brass and used iron for the parabolic covings, and "*meanders* about the fire," on account of its being the most wholesome and lasting material, and also reducing the cost of the apparatus.* While the partners were thus profitably employed, a Frenchman carried the doctor's translation to a brazier, in order to instruct him how to make an apparatus, for which he had contrived to obtain an order from the Duke of Kent,—and "coming to me," says the doctor, "to get a little more light into the matter than he possessed, he showed me the French book, which he said he had written; but upon my calling him M. Gauger, never having seen that author, he told me that he had only written that book jointly with M. Gauger, though I found upon trial that he could not read three pages of his book together. Notwithstanding this, he had the impudence to apply to Count Bothmar (a Hanoverian in great credit at court) and to M. Robethon (a refugee, and French secretary to George I.) to represent him to the King as a poor ingenious man, who had found out a noble invention that deserved a patent; which he could not pay for. His Majesty and those gentlemen were ready to pay for the man's patent, but when I heard of it, I thought it hard that I should by that means be excluded from an invention that had been given the public in French, and which I had since published in English with improvements; and though therefore I was offered half the patent without any expense, I rejected it."†

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* Fires Improved. Append. p. 1, 2.

† Course of Experimental Philosophy, vol. ii. p. 559.

In order to prove that the air was not rendered unhealthy by passing through the iron caliducts in the back of his improved fireplace, the doctor made the following experiment. He bored a small hole in a cube of iron, into which he inserted the end of a pipe, furnished with a cock, that went into an exhausted receiver. He made the cube white-hot, and turning the cock the outward air rushed through the hole and pipe and filled the receiver; and a linnet placed in this air for half an hour was as brisk and lively as a linnet could be. Had the doctor rested on this experiment, in which the bird did its duty to admiration, all would have gone on prosperously, but, to show the effect that "foul burnt air" really had on life, he placed the iron cube in a chaffing-dish, so that the air had to pass through the burning charcoal it contained, as well as through the hole in the red-hot cube, before it entered the receiver. The bird put into this air died in a moment, and a lighted candle was instantly extinguished. This result at once giving soul and body to a prejudice, the cry of "burnt air being fatal to animal life" was raised against the apparatus. A Mr. Worster immediately and resolutely declared against the doctor's method of warming rooms; for "burning the air," he said, destroyed the vivifying spirit which it contained. In support of their hostile opposition, Worster and others who had set their faces against the new fireplace, brought forward an experiment, made by Mr. Hauksbee, in which a bird dropped "stone dead" when placed in air that had been passed through a *small red-hot* brass tube. On this occasion the doctor stood up manfully against his enemies, and appealed to the operation of two fireplaces that heated the library of the Duke of Chandos, and twenty or thirty others that he had erected for various persons, not one of whom found any inconvenience from the use of them. For to avoid all objections, says he, "I *never* brought in the air through *red-hot pipes passing through the fire*, (as his foes said he did); but though I was obliged to bring my conduit for the air round a sea-coal fire, and much nearer it than M. Gauger did, yet I always made my tubes of plate iron, (found to be innocent by experiment,) and of 5 or 6 inches diameter; so that this air was no more heated than it would have been by a summer's sun, and the air introduced came immediately from without doors, so that the whole air of a room was often changed in a quarter of an hour; and had none of the old unwholesomeness and inconveniency of a German stove, where the same air is heated even to the suffocation of those that are not used to it."*

The doctor's appeal was not regarded, and his opponents held his first experiment to be erroneous. It was the "burnt air," said the unrelenting Mr. Worster and his followers, that suffocated Hauksbee's bird; and it was the "burnt air" that choked the doctor's own bird in his charcoal and brazier experiment, therefore burning the air in French stoves is most noxious to the health of human beings; and this obstinate opinion with which Mr. Worster contrived to inoculate the public, produced the same deadly effect on the doctor's undertaking, that the veritable burnt air did on the linnets and candle. After the lapse of six and twenty years, when the indefatigable and ingenious Desaguliers looked back on this misfortune, he was touched with the sorrow of blighted hope, and said, "As I took so much pains and care, and was at some expense to make this management of air useful, I can't help complaining of those who endeavoured to defeat me in it." This attempt to naturalize an improvement being bawled down, the English hearth-fire was left in full possession of its ancient right of exhibiting an example of the manner of consuming the greatest quantity of fuel with the smallest possible return of comfort.

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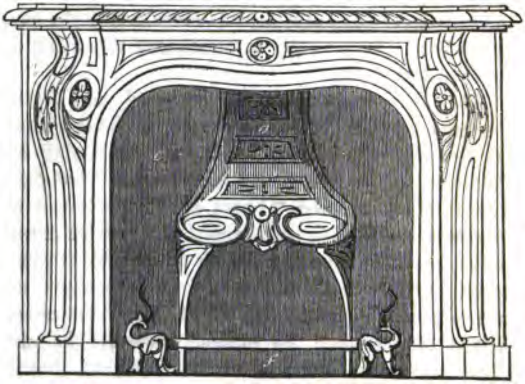
* Course of Experimental Philosophy, vol. ii. p. 559.

The warmth that the Polignac fireplace was calculated to diffuse through the villa and mansion, and at the same time gratify the French partiality for an open fire, was also obtained in the country house and cottage, by the use of the "cheminée de Nancy."

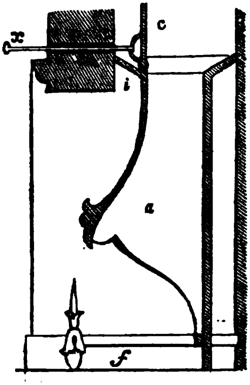
FIG. LIII.



When it first appeared, the historian hath not recorded, but it was in use in 1738, and most probably was a gift to society, from some ingenious and philosophical native of the place, from which its name is derived.

A view of it is given in Fig. LIII., and a section in Fig. LIV. The length of the hearth is regulated by the length of the wood, which seldom exceeds 22 inches.

FIG. LIV.



The canopy, or hood, *o*, placed over it, is of the same width, and projects at least 13 inches from the iron plate, *o*, that is fixed not more than 2 inches from the back wall of the hearth recess, and forms the back of the fireplace. The hood diminishes as it rises, and at its upper end is contracted into a tube 4 inches on one side and 7 inches on the other, making the smoke aperture have an area of about 28 square inches. An area of 36 square inches being found ample enough for the largest fireplace. This tube is carried 2 or 3 inches above the level of the mantel sofite, and is terminated with a valve or register, *c*, which is shut and opened by the rod, *x*, that goes through the chimney breast. The throat of the smoke flue is closed with brick, or with an iron plate, *i*, in which an aperture is left through which the tube forming the termination of the hood is inserted; no air, therefore, can enter the flue from the room, except that which flows under the hood and over the fire.* In cottages and kitchens where large vessels have occasionally to be heated, the lower front edge of the hood, is sometimes raised as high as 18 inches above the level of the hearth; but this, which can seldom be exceeded, is not to be recommended. A height between 11 and 14 inches is found the best. When the height was 13 inches, the length of the billet 22 inches, the projection of the hood 13 inches, and the register kept half closed, to allow an area of about 14 square inches for the smoke, the effect of the cheminée de Nancy in warming a room containing 2288 cubic feet of space, and with a surface of 54 feet square of window glass, was very nearly equal to that of a Polignac fireplace with the same sized hearth, and burning the same quantity of fuel. Each kept the room at a temperature of 56° during a sharp frost, and this temperature it was found could *not* be produced with 2⅓ times more wood when burned on the hearth with its flue altered to the original construction.

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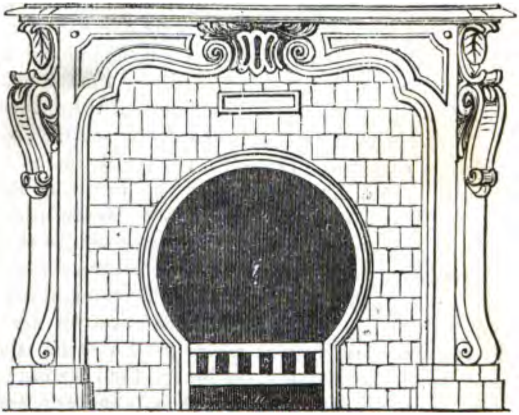
* Traité de Cheminées, p. 135.

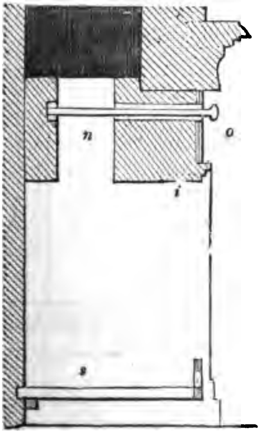
FIG. LV.



The efficiency of this clever apparatus is produced from the front, back, and sides of the chimney being *insulated,* and thus allowing the air in the hearth recess to come in contact with the heated surfaces, and which, being hindered from escaping into the flue, spreads through the apartment above the lower edge of the hood. The portability, moderate cost, and simple construction of the cheminée de Nancy, adapt it above all others to the use of the cottager, and to situations where it is inconvenient to make any alterations on the hearth recess. What a world of comfort would not this simple apparatus produce in an English cottage, as a substitute for those ache-breeding, fuel-wasting grates, with gaping flues and buried in brickwork, that throw away three fourths of the heat of all the fuel consumed in them!

The Flemish fireplace may be described as a sort of mongrel furnace much used in Flanders, a century ago, to warm cabinets and libraries, and praised for saving fuel and possessing the properties of a "poële de fonte," without affecting the head by any emission of carbonic vapour. Fig. LV. shows the front of the fireplace, and Fig. LVI. represents it in section. The width of the hearth, *s*, which is grated, is determined by the length of the billet; the height of the opening, *i*, of the fireplace, above the grate, *s*, is one-third more than the length of the grate. The depth of the hearth is one-sixth of its length. A circular iron frame, having a diameter one-third greater than the width of the hearth, is placed on a line with the face of the jamb; and the spandrels are enclosed with brick-work so as to form the end of a small vault, *i*, that extends backward to the wall of the hearth recess. At the crown

FIG. LVI.

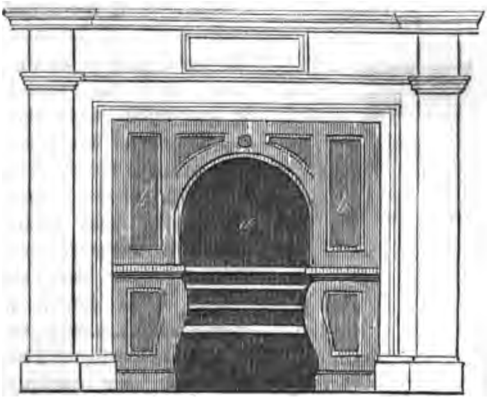


of the arch, under the chimney flue, is an opening, *n*, 6½ inches in diameter, for the passage of the smoke into the flue. This is fitted with a damper, or register, *n*, made of a tile, or iron plate, that is drawn by the handle, *o*, backward and forward to open or shut the passage.*

There is little doubt of the "power of the draught," that was famed, in this fireplace, for being able in all weathers to expel its own smoke from the flue, and at the same time heat the room better with the same quantity of fuel than an open fire could do. The grated hearth for wood fuel may be reckoned a novelty borrowed from the Dutch stove, and the introduction of the "damper" did every thing that could be done with this apparatus for comfort and economy.

Whether the Flemish furnace was the type, or an improvement on the celebrated Bath fireplace is undecided; but it is certain that both warmed the same

FIG. LVII.



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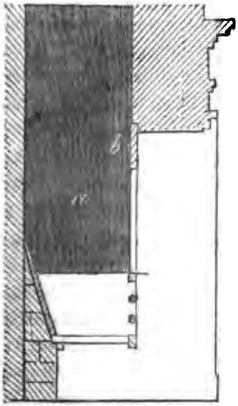
* Traité de Cheminées, p. 130.

generation. If the English apparatus was not invented by some sufferer in the smoke endemic, that in certain winds drew tears from the stoutest eye in Bath, it was a favourite remedy with the local doctors; and continued for a long series of years to be considered, throughout the western districts, not only the best, but the only, cure for an incorrigible chimney; and it must be admitted that in numerous, apparently hopeless, cases, the Bath fireplace did its business effectually; and where the flue was of a good height, it did wonders: the draught carried every thing triumphantly before it; not only the smoke, but all the air in the room, whisked up the chimney with the velocity of a hurricane, followed by all the comfort at a speed as rapid.

The construction of this apparatus, shown in Fig. LVII. and Fig. LVIII., is easy enough. Into a hearth recess of any size fit a "hobbed grate," that fills the whole width, and then close up the space between the hobs and the mantel with an iron plate, *b*, so closely that no air can flow up the chimney except through the "niche," *a*, that is to be left 9 inches high, measuring from the upper grate-bar, and as wide as the bars. No great nicety of dimension is necessary, an inch more or less need not be regarded; spare not your coals, and if the chimney shaft is of a fair height, you will have a roaring fire that will melt gold, and a room in which no corner

FIG. LVIII.



will be without its cutting current; so that whoever, as Beresford in his "Miseries" expresses it, impelled by the "merciless severity of the frost, comes near the grate, he will find his front fried and his rear frozen;" and woe to the unfortunate wight who, being installed in the seat of honour, may enjoy his dignity for an hour or two; he will have to thank his good fortune, not his prudence, if he escape laying the foundation of inflammation, or of ache in every bone in his body.

Effective as the Bath stove certainly was to cure a chimney and cripple its owner, yet there were rooms to be found in upper stories and garrets that were considered as beyond the reach even of its improving power, from which it is clear that the rationale of its action was imperfectly understood; it is not, therefore, surprising that failure in many of these cases was charged against the fireplace, when it ought to have been attributed to the malformation of the flue leading from it. The great width of the smoke canal, and its small height, permitting the descent of air from the top, the column of smoke rose in a flue nearly under the same circumstances, that it would have done had the fire been made in a field; and the descending air mixing with the smoke, lowered its temperature, and thus destroyed its buoyancy. The heavy vapour in the flue during the swellings of a high wind was not only impeded in its sluggish progress, but impelled in rolling clouds into the apartment, until the energy of the furnace reproducing for a moment the elasticity of the bituminous vapour, caused a fitful gleam of a smokeless chamber to soothe, as it were, the irritations of its unfortunate inhabitant. Wherever this fireplace was found, in a garret or in a parlour, it was a most voracious devourer of fuel; and on this account alone a smoke doctor of the highest name declared upon his professional honour, that it was in truth "a monster."

It may here be noticed that the appellation of a "Bath fireplace," in modern speech, is usually given to the lower half of the apparatus containing the coal box. This is a comparatively harmless mechanism, and may even be considered an improvement on the meagre grate or "cradell" that was placed as far back in the hearth recess as the wall would allow, under an open, yawning chimney throat, for the pseudo Bath fireplace was sometimes brought so far into the room as to have the front of its bars on a line with the inside of the chimney breast. The jambs of both sorts of fireplaces were at right angles with the back; and in parlours and dining rooms they were lined with square glazed tiles, got from Holland, on which were daubed, birds, beasts, flowers, and other subjects of natural history, and Scripture pieces, on a white ground; and, "there being so great a variety," says Sir Jonah Barrington, "the father or mother sitting in a winter's evening round the hearth, with the young ones, explained the meaning of the tiles out of the Bible, so that the impression was made without being considered a lesson, and the child acquired a knowledge without being taught: so far as it went, this was one of the best methods of instruction."*

In the fireplace described by Doctor Franklin, in 1745, Prince Rupert's descending flue is cleverly combined with the caliducts in Cardinal Polignac's mechanism. A vertical section of the Pennsylvanian fireplace is given in Fig. LIX., a horizontal section in Fig. LX., and a front view in Fig. LXI. The iron hearth, *f*, has a square opening at *d*, and another at *b*, for the "trap bellows." An iron case, or warm air box, partitioned to form six tubes, or caliducts, is placed on the hearth, with the opening into the lower caliduct coinciding with the square opening *d*. The lower caliduct thus communicates with the air channel at one end, and with the second caliduct at the other; the second opens into the third, and the last of the series opens into the room. An iron case surrounds the series of caliducts on the top, and three sides, and partly in front; a space of 4 inches being left between the upper caliduct and the top plate, and the same space at the back; and the front plate that forms a sort of canopy over that part of the hearth on which the fuel is laid, projects about 7 inches in front of the caliducts. The back of this outer case is detached about 3 inches from the wall *m*, before which it projects in the manner shown

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* Personal Sketches, vol. ii, p. 73.

FIG. LIX.

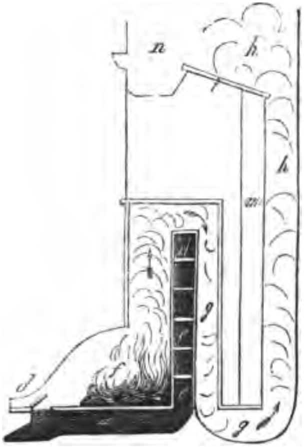
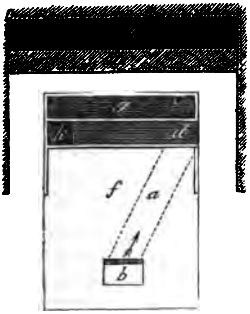
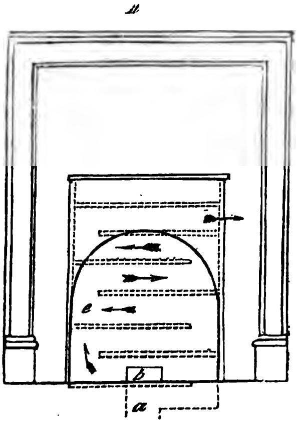


FIG. LX.



in the section; this wall is also 6 inches distant from the back of the hearth recess, and is carried a few inches above the soffite of the mantel, where it receives an iron plate, *i*, that closes the smoke flue towards the room, but is made moveable to allow the flue being cleaned. The space formed by this wall, and the back of the hearth recess is connected with the space behind the caliducts by a curved channel, *g*, and a register is also placed in the flue.

FIG. LXI.



The valve of the soufflet, *b*, being raised, and the fuel ignited, the flame and vapour rise into the space between the top of the outer case and the upper caliduct, and follow the current of air in the chimney downwards into the space between the caliducts and the iron plate; and after heating both sides of the warm air canals, the smoke passes through the curved channel under the wall, *m*, into the flue, *h*.

During this progress of the smoke, the external air rises from the channel, *a*, under the hearth into the first caliduct; and in its course upwards, through the series, receives at each step an increase of temperature, until it issues, at the orifice in the upper caliduct, into the room. The smoke has also heated the front, top, sides, and back of the outer iron case, which being *insulated* from the jambs and back of the hearth recess, the air warmed by contact with these surfaces spreads through the apartment.

The action of this apparatus, it is evident, depends on a steady current being preserved in the smoke flue. Where that is sluggish, or occasionally interrupted, at first lighting a fire, it is often difficult to establish the "draught," and the smoke comes into the room; and to prevent this requires a certain degree of skill not always possessed or exerted by servants. To have the full effect of the warmed external air, it is necessary also to keep the conducting surfaces free from all sooty coating; but as the doctor frames his casing, it is very troublesome and difficult to clean the smoke channels; even when the driest fuel is used, they are soon choked up with sootwens.

The next imperfection is common to the Franklin and Polignac fireplace. The hot air channels were considered to be essential for retaining the external air long enough in contact with the heated metallic surface to raise it to a high temperature; but they nevertheless destroyed in a great degree the useful effect of both fireplaces. In "meandering" through the caliducts, the heated fresh air was deprived of its due velocity, and thus a comparatively small portion was emitted into the apartment at a somewhat greater heat, instead of a large quantity having a lower and more genial temperature. This diminution of effect was most observable in the Polignac fireplace. The action of the outer casing in the Pennsylvanian apparatus was independent of the admission of the warmed external air, and the heating effect of its exterior insulated surfaces being nearly as great as that of a Dutch stove of the same dimensions, the loss of effect from the meanderings of the heated air was not so obvious.

In this design none of Dr. Franklin's usual originality is apparent, yet every part exhibits his great judgment and skill in turning all the heated surfaces to the best account. It was a fondling with the doctor, and in his old age he affectionately calls it "*my* Pennsylvanian stove." The high opinion he had of its calorific powers may be learned from one of the ornaments with which he decorates the canopy, being a chubby-faced *Sun* ogling the epigraph *alter idem*;* and modern experience corroborates all the advantages that the doctor at various times affirmed were to be obtained by the use of his fireplace. It warmed the room throughout; so that every corner was as cozy nearly as the fire-side; the sight of the fire was not impeded so much as it was on a common hearth; the chimney was so entirely closed up, and the warmed air from the caliducts so copious, that

"The icy fang
And the churlish chiding of the winter's wind,
Which bites and blows upon our bodies,"

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* Works, vol. ii. p. 94.

from crevices in doors and windows in all rooms heated in the common manner, was unfelt; while the air of the room was continually changing, and all this was enjoyed with a great saving in fuel.

No one had a more lively perception of the great benefit that even trifling improvements in the art of managing fuel, and distributing heat for domestic purposes, confers on society. "Much more," observes the doctor, "of the prosperity of a winter country depends on the plenty and cheapness of fuel than is generally imagined. In travelling I have observed that in those parts where the inhabitants can have neither wood, nor coal, nor turf, but at excessive prices, the working people live in miserable hovels, are ragged, and have nothing comfortable about them; but where fuel is cheap, or where they have the art of managing it to advantage, they are well furnished with necessaries, and have decent habitations. The obvious reason is that the working hours of such people are the profitable hours, and they who cannot have sufficient fuel have fewer such hours in the twenty-four than those who have it cheap and plentiful —for much of the domestic work of poor women, such as spinning, sewing, knitting, and of the men in those manufactures that require little bodily exercise, cannot well be performed where the fingers are numbed with cold. These people, therefore, in cold weather are induced to go to bed sooner, and lie longer in a morning than they would do if they could have good fires, or warm stoves to sit by, and their hours of work are not sufficient to produce the means of comfortable subsistence;"* and on the effects of the *economy* of fuel, even where it is abundant, he remarks, "that an English farmer, in America, who makes great fires in open chimneys, needs the constant employment of a man to cut and haul wood for supplying them; and the draught of cold air to them is so strong that the heels of his family are frozen while they are scorching in their faces; and the room is never warm, so that little sedentary work can be done by them in winter. The difference in this article of economy alone, shall in a course of years enable the German who burns his fuel in a stove to buy out the Englishman, and take possession of his plantation."

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* Philosophical Papers, p. 37.

Notwithstanding its advantages, this fireplace was not naturalized for fifteen years after its invention. In 1753, Mr. Durno examined a machine made wholly of cast iron, that had been constructed in Philadelphia, and sent to London as a model. Durno essayed to improve the arrangement and adapt it to burn coals; and erected one in his house as a specimen. Instead of the narrow passages for the smoke, which were objectionable in the doctor's apparatus, he made a wide brick chamber, one side of which was formed by the caliducts, and arched it like an oven, leaving a narrow passage in its roof made of plate iron, in which was a register, that "might be turned to such a degree of vent as either to support or diminish the fire."* Mr. Durno said, "I am willing to give my machine gratis, if ever the least smoke is perceived in any room where it is erected, *unless* it may happen at the first lighting the fire, before the air in the funnel is put in motion, but I have never *seen* that happen;" and from the conditional fairness of his promise, it is likely that he never would see a fire lighted where the result was doubtful.

The apparatus was costly: he made three sizes,—for the largest he charged thirteen, and for the smallest seven guineas, which was 27 inches high, 17 inches wide, and 12 inches from back to front. The fuel-box or chamber was 15 inches wide, 5¼ inches deep from the grating to the top bar, 5½ inches from front to back. This kept a room 14 feet square, (and 12 high?) at a temperature between 60° and 64°, when the thermometer out of doors was at 28° F., for 13 hours, with a peck of coals; which, taking all circumstances into consideration, was a great performance.

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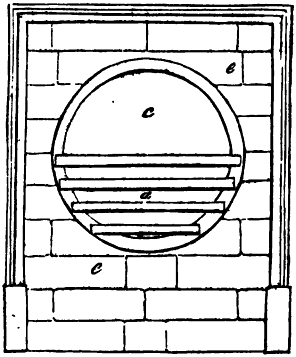
* Description of a New Invented Stove Grate, p. 22.

In reply to some objections made to his stove, more particularly to the fact that it could not at all times be depended on for emitting its smoke, and advising a greater depth being given to the canopy, Mr. Durno observed,* that the canopy was immaterial; and in illustration of his opinion, he notices a scheme practised among artizans who required braziers to free their workrooms of the charcoal vapour. They made a hole, 8 or 9 inches square, in the wall, which communicated with an iron funnel several feet high, that was fixed on the outside. The lower edge of this hole was on a line with

FIG. LXII.



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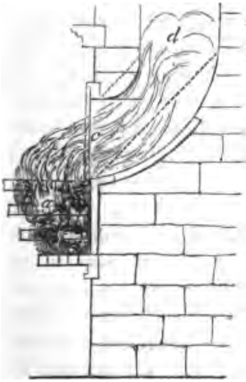
* Appendix to Description, p. 6.

the top of the brazier, which was set against it; and the smoke was carried as clear through the opening into the funnel, as if a hood had been placed over it; and the same thing, he adds, is seen in the stoves about London, that are called "taphouse grates;" which of all known methods of burning fuel where the radiant heat only is desired, is the most simple and perfect—unapproached and unapproachable, except by a return to the hearth in the middle of the room, or to a fireplace like that in the great guard-room of Connisborough Castle.

FIG. LXIII.



The opening, *e e*, of the hearth recess is built up, leaving an aperture, *c*, from 7 to 9 inches high, and of the width of the fuel grate. The back of the aperture joins the upright back of the flue in a curved direction, as shown in Figs. LXII. and LXIII. and its lower part near the fire, is lined with a plate of iron; or the back of the aperture is made slanting, as shown by the dotted lines, and laid with a fire-brick instead of the iron plate. The upper bar of the fuel grate, *a*, is level with the sole of the opening, as in Fig. LXIII. The "draught" is increased by lowering the height of the opening over the fuel grate to bring the air that enters the chimney nearer the fire; but when this height is less than 7 inches the great velocity of the current into the flue, excites a combustion so vivid, that housekeepers who look to the quantity of fuel consumed without referring to the quantity of heat thrown out, think it an extravagant burner, and prefer a 9 inch opening. When higher than this the current is so reduced in velocity, except when the fire is large and burns clear, that an accidental motion of the air from persons passing quickly in front of the fireplace, or opening a door, has a tendency to bring the smoke and dust into the room,—an objection common to fireplaces on every construction.

The fireplace in the House of Lords was designed as an improvement on the Polignac apparatus. The outward air from below the house entered under the iron hearth plate, which was formed with meanders, or "a recurved canal," and thence passed up the back in like turnings and windings near to the top, where it divided, and entered two tubes of copper, one placed on each side of the tunnel, of a sufficient length to reach above the cornice of the room. These main caliducts were then connected to other pipes, one of which was carried round the room and opened opposite the fire, and the other caliduct branched off in an opposite direction; they were perforated, to let out the air. A valve was placed at some distance from the fire in each pipe, which was opened by a thumb-latch, and the heated air was discharged near the *ceiling* from the perforated pipes; so that it was next to an impossibility to warm the house with the greatest fire that could be made in it. On this extraordinary arrangement Mr. Durno observes drily, that it would have been better to have discharged the warmed air from the hot iron back plate, and then it would have ascended to the ceiling *naturally* without the aid of pipes, and warmed the circumambient air. The effect expected from this chimney was preposterous, for only 8 square feet of the surface of the back plate or caliducts was warmed by the fire. Some alterations had most likely been made on the apparatus after its erection, by Dr. Desaguliers; for he states, that the air from *his* stove was diffused throughout the house, and warmed every body very comfortably.[*]

The air to supply these fireplaces was not always taken, as in this one, from under the floor, or at its level. In several constructed by Mr. Durno, he says, that he followed a contrivance practised by Dr. Desaguliers, to avoid the introduction of *dusty* air into the caliducts of a fireplace that he made for Lord Burlington. A flue was cut into the wall, which reached 26 feet above the floor, and opened at its upper end to the outward air, and at its lower end into the caliducts behind the fire, by which means the air that came into the room through the iron meanders had no taint whatever.[†]

This clever expedient is one that was recommended by Cardinal Polignac, and which has been noticed in a previous page.

By English improvers of chimneys, sea-coal is considered the exclusive aliment of fire. The ancient use of wood for firing, that had lingered thus long in inns, was now giving way. A tourist describing the source from whence London was supplied with wood fuel, notices the decay in the supply and the cause. "We go over Shooter's Hill, he says, where we have a chalky soil and far from rich, much overgrown with coppice wood, which is cut for *faggots* and for bavins, and sent up by water to London. Here they make those faggots which the woodmongers call *ostrey* wood, and in particular those small light bavins which are used in the taverns in London to light their faggots, and are called in the taverns a *brush*, and by the woodmen *pimps*. 'Tis incredible what vast quantities of these were laid up at Woolwich, Erith, and Dartford, but since the taverns in London are come to make coal fires in their upper rooms, that trade declines."[‡]

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[*] Course of Exper. Philosophy, vol. ii. p. 686.
[†] Durno. Description, &c. App. p. 7.
[‡] Tour through Great Britain, p. 129.

When the dwellings in the time of King William are compared with those of this period, the improvement appears very great. The arrangement of the houses of the lower classes in particular was more convenient, and their finishings and furniture incomparably neater and more comfortable. Carpets, that were the luxury of the wealthy, are now so common as to be spread on the stairs and passages in small tradesmen's houses. Doors and windows are much better fitted, casements are replaced by suspended sashes, and the fireplace and flue are beginning to attract a large share of attention. In general, however, the construction of the houses has not kept pace, as far as the choice of materials is concerned, with their decoration and furnishing. Walls, floors, partitions, roofs, and above all, their stairs and landings, are of combustible wood. Here and there a brick wall may separate contiguous premises; but, in general, the bulk of the houses are without that protection, and whole neighbourhoods may be said to live in the dread of their lying at the mercy of any drunken fellow, or thoughtless servant or child, not properly extinguishing a snuff of a candle, and exciting a conflagration from which there was rarely any means of sudden escape, other than a fire-ladder; and hence the distressing loss of life that aggravates the calamity of the frequent desolating fires at this period, which made Bishop Berkley, in his ingenious and benevolent queries, compare such houses to fire-ships; and streets and towns, as so many squadrons and fleets of them met together for the certain purpose of mutual destruction.

ESSAY X.

It has been remarked that most diseases in all countries have external, and for the greater part *removable* causes; but these being familiar to us are, in the common bustle of life, overlooked or undervalued, and though all may regard them as injurious to their comfort, few will believe they have power to ruin their constitutions.

The action of contaminated confined air has been seen among the most potent and insidious of mortiferous agencies. *Any* addition to the natural atmosphere that we breathe, must be a deterioration, and absolutely noxious in a greater or less degree; and health, says Thackrah, would immediately suffer, did not some vital conservative principle accommodate our functions to circumstance and situation. But this seems to get weaker from exertion. The more we draw on it, the less balance it leaves in our favour. The *vis vitæ*, which in a more natural state would carry the body to seventy or eighty years, is prematurely exhausted;* and like the gnomon shadow, whose motion no eye can perceive, but whose arrival at a certain point in a definite time is inevitable, the latent malaria, which year after year seems to inflict no perceptible injury, is yet hurrying the bulk of mankind with undeviating, silent, accelerating, rapidity to an unripe grave.

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* The Effects of Arts and Trades on Health, p. 30.

Pure air is the food designed by nature for the constitution. Man subsists upon it more than upon his meat and drink; and there are numberless instances of persons living for months and years on a very scanty supply of aliment, but no one can subsist for a few minutes without a copious supply of the aërial element. It ought also, in reason, to convince us, says the indefatigable Hales, of the great importance that plenty of fresh air is to our welfare, when we consider that the great Author of Nature has allotted near one half of the trunk of our body for the office of respiration or breathing only; were an animal to be formed of the size of a large house, we are well assured, by what we see in other animals, there would be ample provision to furnish it with a constant supply of fresh air by means of *large lungs* formed to inspire and breathe out air in the manner ventilators do;* and it cannot be an unprofitable project to furnish houses with the wholesome breath of life in exchange for the noxious air of confined places, which is the occasion of disease and death to multitudes.

The want of *house lungs* must have been felt in every community, and it has been noticed in a previous Essay, that, as a means of cure, an ancient physician endeavoured to ventilate rooms by thorough "draughts;" and Celsus recommends a large room for a person ill of fever, or a small fire to be made in it to clear the air. The ancient baths had a contrivance in the roof to regulate their temperature, and perhaps their ventilation, and similar openings it is probable were not rare in private rooms, where numbers were congregated; but the schemes practised at all times in Eastern countries to change the air, must be considered more as means to cool than purify the apartment. Mines were sometimes ventilated by a fire suspended in the middle of the shaft, to create a circulation and "draw up" the foul air; and Agricola, in his book De Re Metallica, describes a mechanical contrivance for injecting air into them by means of a rotary fan; large bellows had been used with the same intention.

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* Description of Ventilators, p. 39.

In English houses there seems to have been no other ventilating process except to open a door or a window, or a hole in the wall, or ceiling;* and it was in this way that Sir Christopher Wren attempted to ventilate the House of Commons. At each corner of the house, in the ceiling, he made a large square hole, which was the bottom of a truncated pyramid, that was carried 6 or 8 feet into the room over the house, and could be opened or shut perhaps with a sort of lid. Through these holes the breath of the people below, and the steam of the candles, issued into the room in which the pyramids were placed. But it often happened, that when the pyramidal funnels were opened, the air above, being colder and denser than what was in the house, descended through the pyramids and annoyed the persons that sat beneath them.

Dr. Desaguliers, who was called upon in 1723 to remedy the inconvenience, discharged his commission with great ingenuity, and so as to retain the pyramids and the roof in the state they were left by Sir Christopher.

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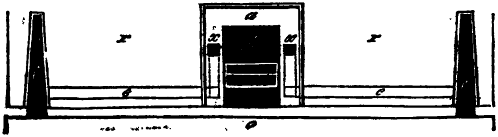
* Unless it were to get rid of bugs and their effluvia, that infected to a nauseous degree even the cleanest houses from the prevalent use of wainscot linings. In this case, Hales says, that in London and in the country, houses were fumigated by the use of a large iron pipe or tube 6 inches in diameter, standing without doors on a proper stove, with brimstone and charcoal burning together, and the fumes were conveyed up in at the window.—Des. of Ventilat. p. 54.

He built two closets, one at each end of the upper room, between the pyramids, and leading a trunk from the pyramids to the square cavities of iron that went round a fire-grate fixed in the closets, as soon as a fire was lighted in the grates the air came up from the house through the heated cavities into the closets, and so went away up their chimneys.*

Fig. LXIV. will give a notion of this arrangement; *c c* are two of the pyramids, *e e* two pipes leading from them to the fire-grate, and *o* its chimney. The heat of the fire rarefying the air in the iron cavities, *x x*, a current was produced in *e* and *e*, and the air from the pyramids flowed at *x* into the closet, *r*, and thence into the chimney, *b*.

FIG. LXIV.



In 1727 the doctor designed a machine for the Earl of Westmoreland, to clean a mine of foul air, whether of greater or less specific gravity than the atmosphere. It consisted of a triple iron crank, a foot long, working three copper-barrelled pumps, of 18 inches internal diameter, which by means of three regulators were alternately applied, to force air into a place, and extract it through trunks or pipes that were 10 inches square in the inside. The engine worked with a great deal of ease, and there being little atmospheric pressure or weight to be removed, and only the resistance from friction in giving a moderate velocity to the air in the pumps, one man was able to discharge 10 cubic feet in a minute.

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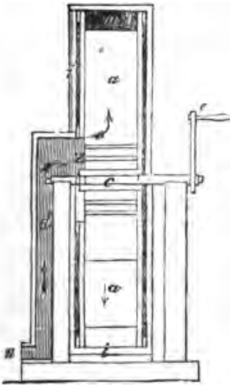
* Course of Exp. Phil. vol. ii. p. 560.

Seven years afterwards he exhibited to the Royal Society a model of a machine for "changing the air of the room of sick people in a little time, either by drawing out the foul air or forcing in fresh air, or doing both successively, without opening doors or windows," which he thought would be of great use in all hospitals and prisons, and also serve to convey air into a distant room, "nay, to perfume it occasionally."

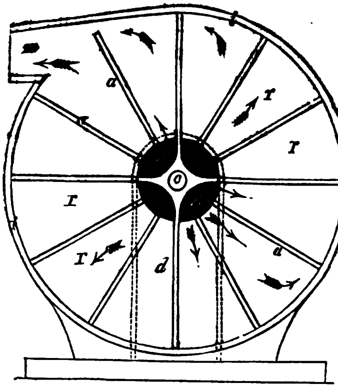
The wheel shown in Fig. LXV. and Fig. LXVI., is described to be 7 feet in diameter and 1 foot wide.

FIG. LXV.



The 12 radiating partitions, *a a*, approached to within 9 inches of the axis, leaving a circular opening, *z*, 18 inches in diameter. The wheel was enclosed in a concentric case, *i*, which had a "blowing pipe," *m*, on the upper part of its circumference, and a suction pipe, *n*, that communicated by a funnel, *d*, with the central opening, *z*, in the wheel, which was turned by a handle, *e*, attached to the axis, *c*, that went through the case and rested on a standard. The "fanner" was adjusted to revolve easily, but as closely to its concentric casing, *i*, as possible, and it had no communication with the air except through the suction and blowing pipes. By the revolution of the wheel, the air entering through the central opening into the spaces, *r r*, formed by the radiating partitions, was thrown by the centrifugal motion towards the circumference, where it was confined by the concentric casing, and carried round until it arrived at the opening of the blowing pipe, *m*, into which it was impelled by each radiating partition in continuous revolution. When the suction pipe, *n*, was open to the atmosphere, or to a space con-

FIG. LXVI.



taining heated air, and the blowing pipe connected with a room, the apartment was filled with cold, or with heated air, in any desired quantity, by increasing or diminishing the speed of the wheel. If foul air had to be drawn out, the suction pipe was connected with the room, and the blowing pipe with the atmosphere; and when it was not required either to draw out foul or introduce fresh air, but to keep the *air of the room in motion* only, the suction and blowing pipe both opened into the apartment.

The thermo-ventilator at the House of Commons became an object of hostility to an individual whose feelings and "perquisites" had been hurt by its erection. Mrs. Smith, the housekeeper, not liking to be disturbed in her possession of the rooms of which she had the use, did what she could to defeat the operation of the ventilating closets; and her perseverance and "science" enabled her not only to baffle the good-natured philosopher, but to stand clear from the reproof of the "House" itself, that she diurnally stifled. Mrs. Smith's system of tactics was formed on the negative principle, and "she carried her point by *not* having the fire lighted until the House had sat for some time, and was very hot; for then the air in the closets descended into a rarer air, and it became hotter instead of cooler. But when the fire was lighted, before the meeting of the members, the air ascended into the closets and out of their chimneys, and continued to do so the whole day, keeping the house very cool."[*]

Sir George Beaumont, and some other members "observing, that the design of cooling the house was frustrated, in 1736, asked me, said the doctor, if I could not find some contrivance to draw the hot and foul air out of the House by means of some person that should entirely depend upon me; which I promised to do, and effected, calling the wheel a centrifugal or blowing wheel, and the man that turned it a ventilator. This wheel, in some things like Papin's Hessian bellows, differs much from it; being more effectual, and able to suck out the foul air or throw in fresh, or to do both at once, according as the Speaker is pleased to command it, whose order the ventilator waits to receive every day of the sessions."

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[*] Course of Nat. Phil. vol. ii. p. 567.

The doctor does not state what the dimensions of this apparatus were, but refers to his model, which is shown in Figs. LXV. and LXVI. in a previous page.

The necessity of some means of airing ships also was at this time forced upon the attention of Government by the bad health of the troops that were embarked at Spithead to proceed on an expedition against the Spaniards. Numbers were relanded, and sent to the hospitals for fresh air, and the ships "stunk to such a degree that they infected one another."

"The Lords of the Admiralty applied to Dr. Desaguliers to show them the model of his centrifugal wheel and air pipes; and after the exhibition, some of them went to see the operation of the wheel fixed over the House of Commons. Sir Jacob Ackworth, the Surveyor of the Navy, attended them, and seemed to approve the machine as much as they did; and the doctor was ordered to make a blowing wheel, with its pipes, to be tried on board the Kinsale, at Woolwich, but less than that at the House of Commons, that it might not take up too much room in the ship." *

The doctor, with his machine and carpenter, were in readiness at the time appointed—but Sir Jacob,

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* Course of Nat. Phil. vol. ii. p. 568.

who did not attend, delegated another officer to witness the experiment.

This ventilator was a small affair, for the suction and blowing pipes were only 3 inches by 5 inches in the clear; but, nevertheless, the smoke that had been made in the carpenter's room with pitch and other smoky substances, was drawn as black as from a chimney above deck with a few revolutions; and on the valves being reversed, it forced the air between decks with the same energy. All the persons present commended its operation; and the Knight himself, at an interview with the doctor, seemed to have so good an opinion of it—that he graciously informed him he should not require his attendance at the next experiment, which could be performed by the carpenter, Kembel Whattley.

On this occasion, says Mr. Whattley, in a letter to the doctor, "when Sir Jacob came on board, he was very complaisant to me, and asked me if I was the person appointed by Doctor Desaguliers to attend him in order to try the experiment of the air machine, and I told him I was. Then said he to the men, hoist the windsails; and the windsails were hoisted. Now says he to me, we have cut two scuttle holes at each end of the ship, and you shall see what the windsails will do; it is our *old way* when at sea. I was then called for, to see that the wind sails would blow out a candle at one of the scuttle holes. Now, said he, I would have you work the engine, and see whether that will throw out so much air as our windsails you see do. Lord, Sir, said I, that I imagine was not the intent of the thing; it was to draw out the foul air from any part of the ship that there were tubes to convey it from. It is impossible that a thing which is but 3 inches by 5, should throw in as much air as a thing 2 feet 6 inches in diameter. So we talked awhile, and at last he told me that he could not stay—but that he had thought so before, and that he was sorry that the machine would not do: Pray, Sir, said I, let there be a great smoke made in the carpenter's store-room, and see whether the engine or your windsails will destroy it first. Then he told me that he could not possibly stay; but that gentleman there, said he, pointing to a pretty lusty man that was present, shall be with you, and he and you may try the machine as you please; and I shall think the same of it from his report, as if I were present. So, Sir, it was then left to the gentleman and me to try it; and I burned the pitch in the carpenter's store-room, and made a great smoke, and ordered the engine to be worked, and it drew it out in less than five minutes time. Then I turned the valves and brought in fresh air; and, as I thought, it gave the gentleman entire satisfaction. We then made as great a smoke as before, and put down the windsails, and the smoke was driven into several parts of the ship; and that not in half the time that your engine did it in, and then it went out above deck. Sir Jacob told me afterwards, that he was sorry that the doctor's wheel succeeded no better, but he thought it might be a very *pretty thing* in a house! Sir Jacob desires his humble service to you!" And shortly after Sir Jacob finally gave what Mr. Cobbett called the "shuffling kick" to the centrifugal ventilator, and its accomplished contriver.

Whattley's long story is very instructive, as a history of the good old official manner of passing judgment on an invention. "Not one of the Lords of the Admiralty, who talked of having many of the ventilators made for the preservation of the health of the persons then going to Jamaica, condescended to witness one experiment; and Sir Jacob, who condemned the thing, would not once be present to observe its operation. But thus ended my scheme, says the doctor, which I hoped would have been of great benefit to the public."*

Mr. Samuel Sutton was a brewer, who, touched with compassion for troops in such unhappy circumstances as were those lying at Spithead, "felt himself obliged to do all that was possible for their relief:" and sustained by this laudable motive, and on account of the great benefit that his apparatus was calculated to confer on mankind, and to the navy in particular, he underwent all sorts of slights and humiliations to get it introduced into vessels of war.

In his narrative, Mr. Sutton gives a very circumstantial history of the origin and progress of his "system;" the principle of which he discovered by accident. Finding on one occasion, when he had stopped the air out of a room that had three fire-places, and making a large fire in two of them, that he could bring the wind down the third chimney with such force as to put out a candle, he concluded, that a fire being always kept on board ship, and a pipe or cavity made to the well, one end of it being heated by fire, a change of air would follow, and by this the air in it would be rendered sweet and pure, and fit for respiration; and from that time he made it his business to consult officers and sailors of the navy concerning the importance of ventilation. "I particularly remember," he says, "that being at a coffee-house near the Admiralty, I placed myself nigh some gentlemen of the navy, and inquired of them, as I had before of others, as to the usefulness of a change of air: all, to a man, acknowledged it would be of the utmost service. I told them I could procure it: upon which one of the company went to another table, and the rest followed him; and I heard him tell the others that he heartily pitied me, as being really mad and out of my senses."*

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* Course of Nat. Phil. vol. ii. p. 568.

From this anecdote it is evident that, although sane, Mr. Sutton, was an aspirant for the patronage of the Admiralty, of a different order to the sensitive Desaguliers. The interview that he solicited was, however, granted by one of the "Lords," who gave him a letter to Sir Jacob Ackworth; and on presenting it, a meeting was appointed five days afterwards, at seven in the morning. Mr. Sutton was punctual, but the Knight, immersed in business, detained him in waiting until the evening, when a short colloquy took place. "Sir, I suppose you intend to throw air into the wells of ships?"—"No; I propose to draw it out by means of fire."—"Do you know how far you are to draw it out?"—"Not 6 inches; for if I can extract it ever so small a distance, the incumbent air will press forward, and cause a constant change. I hope you will appoint a time for an experiment to be made of my scheme?"—"No experiment shall be made, if I can help it," muttered Sir Jacob.

Noway heart-fallen by the Knight's resolution, Mr. Sutton petitioned "their Lordships," and obtaining an order to make an experiment in a ship of war at Woolwich, he proceeded forthwith to erect his apparatus; when one morning, as the plumber had the grozing iron in his hand to complete it by finishing two joints, an officer made his appearance from head-quarters, furnished with peremptory instructions to take down the ventilating apparatus and plug up the holes. In this discouraging predicament Mr. Sutton introduced himself to Dr. Mead, physician to the King, who lent a friendly ear to his story, and brought Mr. Folkes to favour the project. The doctor read an account of the invention to the Royal Society, and applied to Government in Mr. Sutton's behalf; who was thereupon ordered to try his apparatus in a hulk at Deptford. In September, 1741, the Lords of the Admiralty, and a great many other persons, met to witness the experiment, when Sir Jacob was pleased to say, in the hearing of them all, "I am sorry you are come to see such a foolish experiment, that I tried myself yesterday, and it would not shake a candle." Mr. Sutton, feeling the strength of his friends, and chuckling over the Knight, retorted, "It would be in good humour to-day, and every one of the pipes would *blow out* a candle."

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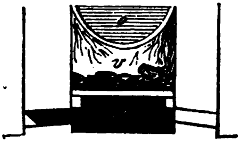
* Historical Account of a New Method of Extracting Foul Air p. 5.

The best proof of all being satisfied with this exhibition, was an order to fix a ventilating apparatus in the Norwich man-of-war, about to sail for the coast of Guinea; and it was, perhaps, with an eye to the possibility of Sir Jacob exerting his intermeddling propensity to keep things in the "old way," that in Sir Charles Wager's instructions to the commissioner of the dockyard, it was expressed that Mr. Sutton "was to meet with no obstruction or discouragement from any body that may think themselves wiser."

FIG. LXVII.



To boil the provisions of the ship's company, there was a copper fixed in the brickwork, with a door to the fireplace, as shown in Fig. LXVII., Fig. LXVIII., and Fig. LXIX. Mr. Sutton enclosed the ash-pit, *u*, with a door also, and laid small pipes, *r*, *s*, *t*, through the sides, and opening into the ash-pit under the fire-grate; to these pipes others were joined, which were carried to the bread room, orlop and well, and other parts. When the fire was lighted under the boiler, and the ash-pit door, z, shut, the air rushed through the pipes, *r*, *s*, *t*, to supply the combustion, and drew all the stagnant air from those parts of the ship into which the pipes were carried: and this current continued after the fire under the boiler was extinguished, as long as the materials of the fireplace were heated. By this means all the foul air in the ship was incessantly carried through the pipes into the fire, and thence by the chimney above deck, and its place was

FIG. LXVIII.

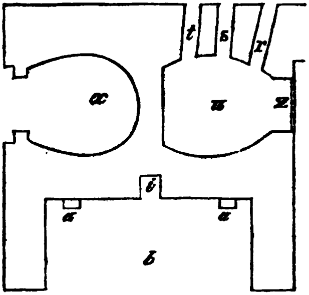
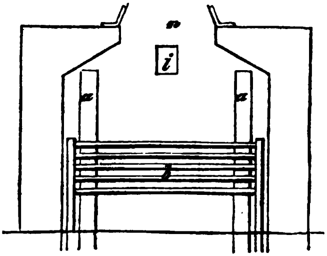


FIG. LXIX.



occupied by the fresh air from without. In the ship there was also an open grate, or range, *b*, Fig. LXVIII. and Fig. LXIX.; and that its heat might be turned to account, Mr. Sutton placed two pipes, *a*, *a*, behind the grate, which were carried about 30 inches above the upper grate bar, where they opened into the flue, *r*. At their lower end they were attached to other pipes that were carried into another part of the ship. These pipes got very hot at their upper extremity; a strong current upward was thus produced in the pipes connected with them, and drew the stagnant vapour from the places into which their lower ends were inserted; and by these simple means, a most salutary change of pure air was introduced in places wherein hitherto the air had been stagnant and offensive.

Dr. Hales, distinguished for his ingenuity in experiment, had written to Dr. Martine, who was attached to the armament lying at Spithead, to suggest a method of fumigation, should infection make its appearance during the expedition. The doctor's attention being drawn to the subject by this correspondence, mechanical ventilation afterwards occurred to him as a means for preventing the effects of malaria among mariners; and he read an account of a perflating apparatus of his contrivance, before the Royal Society, about two months after Dr. Mead described the "Suttonian system." And shortly after, he was applied to by the Government for some information regarding his ship's lungs, and desired to fix one on board the Captain, a seventy-gun ship, as an experiment: this was in progress when Mr. Sutton's pipes were demolished. The ventilator is shown in Fig. LXX. and Fig. LXXI. The box, or outer case, *a*, was 10 feet long, 4 feet 3 inches wide, and 13 inches deep inside. The *midrif*, or valve, *x*, was framed of wood, and fixed at one end to the case by strong iron hinges; and a slip of leather was nailed over the whole length of the joint, to make it air-tight. The midrif moved easily upwards and downwards, as near to the surface of the outer case as possible without occasioning any resistance from friction. An iron rod, *o*, was fixed about 6 inches from the moveable end of the midrif, which had a joint made like two links in a chain, to allow it to preserve its perpendicular position in the motion caused by the rising and falling of the midrif. The upper end of this rod was attached to a lever, *n*, 12 feet long, that moved on a pivot at *i*, and which was worked by two men. The valves, *e e* and *u u*, each 22 inches long, 6 inches deep, and suspended by copper hinges, were an inch broader and longer than the openings; and their borders, as well as the corresponding borders of the valve openings, were lined with list, or woollen cloth, to deaden their noise when falling. There was a large aperture, *r*, in a box which covered the emission valves, *u u*, from which the air

FIG. LXX.

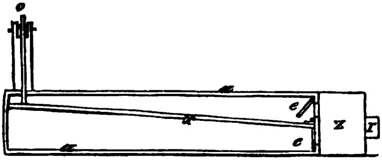
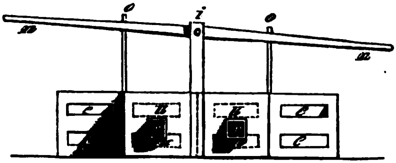


FIG. LXXI.



was conveyed by a pipe into the part of the ship that was to be ventilated.

The construction of the ship's lungs differs little from that of the common bellows. The operation is nearly the same. The air enters by the valves, *e e*, which are hinged to open inwards; and is emitted at each rise and fall of the midrif through the valves, *u u*, hung to open outward into the box, *z*, from which it is conveyed through the tube, *r*, to the parts of the ship that are to be ventilated.

The doctor calculated that this machine would expel a tun of air at each stroke, or six tuns a minute, by two men working at the lever, *n n*, and that the air issued from the aperture, *r*, with a velocity of 25 miles an hour; but as the openings at which it was admitted to the deck had an area of 105 feet square, the current was so gentle as not to be perceived. But by hingeing the midrif he diminished the effect of his ventilator one half, when compared with the air-pump of Desaguliers; and modern experience would not, perhaps, rate its effect at more than two fifths of the doctor's estimate. He describes other combinations of his ship's lungs on a smaller scale, and with a horizontal movement of the midrif. All are simple, easily constructed and repaired, but have now rather a historical than practical value.

Sir Jacob superintended the experiment in the Captain; and as the doctor makes no complaint of the "dock-yard bear," it is likely he behaved with more impartiality on this than on other occasions. In his treatise, the doctor combats some adverse opinions, without formally stating them to be those entertained by the Knight. As to the labour and difficulty of working these ventilators, which is the principal objection urged against them, says the doctor, how frivolous and groundless is it when the matter is considered! They are chiefly wanted where there is a great number of men. If two men can hold to work them for a quarter of an hour, four men, by changing hands, spell and spell, as they term it, may well work for an hour. And suppose there are five hundred men in a ship, and each one takes his share, then once in five days it will come to each man's trice to work an hour. But suppose a fifth of the hands be deducted for officers and sick, and the ventilators be required for half the time only they are on board, each man will not require to work half an hour in eight days. Is not the benefit proposed, the saving of life, a sufficient reward for so small a pittance of labour? It is well known that all must perish in a ship, if they will not be at the pains to work the pumps at proper times; and should not the same motive of self-preservation induce them cheerfully to work the ventilators? One would think it needless to use any arguments to make men follow so easy and certain a way to preserve their own lives and that of their comrades. I cannot believe, continues the doctor, that men will choose to *sicken* and *die* in a *stench* in an *old experienced way*, when they have it in their power to prevent it by rational and effectual means; or that the British sailor, rather than pull his hand out of his bosom, and work for an hour once in ten days, will choose to lie down, and suffer his brave, manly spirit to be suffocated in a frowsy stench that has destroyed the lives of millions of the stoutest and bravest.*

It is not, according to the doctor, ventilating a ship with a windsail when the wind and weather will permit, that will suffice. A gentle supply of fresh air is not necesssary only now and then, but incessantly, in the same manner as animals are supplied therewith, whether *sleeping* or *waking*, if a due regard be had to the health of the mariner. It is for want of being thoroughly sensible of the vast quantity of rancid noxious vapours which are incessantly exhaling from a great number of live human bodies confined in a close place, that makes many apt to imagine it to be sufficient for health, if such bad air be ventilated away, and exchanged for good air, at the distance of many days between each ventilation; and it is through the same ignorance that others are not to be persuaded that such air is unhealthy, when they are warned by its offensive smell; and though the offensiveness does much abate by use, that makes it more fatal, by rendering it more insidious. Windsails, that have been used time out of mind for freshening the spaces between decks, are very imperfect ventilators, for they cannot be let down in bad weather, when the hatches must be shut, at which time they are most wanted. They also admit such large volumes of cold air, that they cannot be introduced to those spaces where the men are asleep; nor into many parts of hospital ships, without incommoding the sick; nor into places where its admission should at all times be regulated with reference to its temperature and moisture. Ventilators are of infinite use, not only when the ports are shut, but in a calm, when windsails are useless, and would often preserve the lives of animals that are destroyed in the voyage, when it is necessary to keep the hatches closed.*

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* Description of Ventilators, p. 36.

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* Sir Martin Triewald, military architect to the King of Sweden, in the spring of 1741, invented a machine to draw out the bad air from under the decks of the Swedish ships that blockaded St. Petersburgh, which it did at the rate of 36,172 cubic feet of air in an hour; and in October following, he had a patent granted to him by the King of Sweden. In the summer of 1742 one of his engines for a sixty-gun ship was sent to France, which being approved by the Royal Academy of Sciences, the French men of war, says Sir Martin, were ordered to be furnished with them. In the same year every

Dr. Desaguliers was displeased, that all mention of his blowing wheel should have been omitted in the "Description of Ventilators." I hope, he says, that Doctor Hales will be rewarded as he deserves for such a noble proposal; for his ventilators, if used, will save the lives of thousands who perish by breathing unwholesome air every year. Or if he find a combination against him, as I have done on the same occasion, he still will be commended by wise and good men, which is a reward in the midst of disappointment. As I have made experiments these twenty-eight years, upon purifying air, conveying it from place to place, and changing it for the advantage of those that breathed in close places to the detriment of their health; and still, to use the vulgar expression, have been *jockied* out of my project, I should have felt it a sufficient reward, if the doctor had mentioned ever so slightly, that I had made some experiments that way—nay, though he had said, that my blowing wheel which he had at Teddington to make trial of, did not blow nearly so strong as his bellows, and therefore must be much worse: but I believe the doctor was in such haste to publish his ventilators,* that this omission was pure forgetfulness. On the same occasion, Mr. Sutton, with little grace, also expressed surprise, that no notice was taken of his system of "ventilation by fire," by the candid author of the Description of Ventilators. But Mr Sutton, in his turn, forgot to mention Desaguliers, of whom both he and

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Swedish man of war and hospital ship was equipped with his ventilators, in consequence of its being observed that the preceding year was a very sickly one in the Swedish fleet, except in the ships that had been furnished with his experimental ventilators. In hospitals and barracks for the sick, Sir Martin placed them in the garret, from which two or three pipes went down several inches through the ceiling into each room where the sick lay, and drew out the corrupted air. In men of war and hospital ships he placed the ventilator on the upper deck of the great, or any other hatch, and the suction pipe was carried down between decks, which effectually cleared them of stagnant air."—Hale. Des. of Ventilators, p. 12.

* Course of Nat. Phil. vol. ii. p. 560.

Dr. Hales were not imitators but unacknowledging borrowers, for the ship's lungs did not differ much from the machine designed for Lord Westmoreland, and the fire ventilator was a variation only of Desaguliers' first method of ventilating the House of Commons.

Soon after the sailing of the Norwich, Mr. Sutton petitioned for "a suitable reward for his useful invention, reasonable satisfaction for his trouble, loss of time to the neglect of his other affairs, and expenses in the execution." All his applications to the Navy Board remaining unnoticed, and being "justly moved at the cold and unkind treatment he met with, he freely expressed his sense of their hard usage, in a petition to the Lords of the Admiralty, in which he stated, that he found to his extreme surprise that he was not likely to receive any reward, nor his Majesty's sailors any benefit from his invention, though it is universally acknowledged, more of them have lately died in America for want of good air than by the Spaniards." This petition was treated as uncourteously by the Admiralty, as the others had been by the Navy Board. In the meanwhile the Norwich returned to England, and her captain, knowing perhaps the unfavourable feeling towards the ventilators in influential quarters, stated that he was obliged to "stop up two of the air pipes that were put on board, because the fire came down between decks. The other pipe to the well was kept open, but the ship making water enough to keep her sweet, he was not able to judge of their use, having been so healthy as to bury only two men, all the time he was on the coast." A copy of this truckling statement was given to Mr. Sutton, as an answer to all his petitions.

Mr. Sutton had now, however, something to stand upon. "This good health," says he, "was more extraordinary than had ever before been known. The people at Barbadoes on that account doubted, whether the

Norwich had been at Guinea or no. The gentleman it seems lost so few men, that he could not discover the usefulness of my pipes; but had he lost the greatest part of his crew, I dare say he would have been able to judge, that my pipes were of no service at all;" and he appealed to Sir Jacob himself to do him justice. "Honoured Sir," writes Sutton to the Knight, "when a scheme is proposed for the good of mankind in general, and the preservation of the lives of his Majesty's subjects in particular, it is a matter of great consequence and importance that a strict inquiry should be made whether it will effectually answer the end proposed. I entreat you to be so good as to inquire whether the apprehension that my pipes will expose ships to the danger of fire be not entirely groundless, as your declaration on this point, in my favour, would have great weight." Sir Jacob was silent.

The letters that Mr. Sutton addressed to the Earl of Winchelsea also had lain unanswered; but he now memorialized his lordship again on the unfair report of the captain of the Norwich, and pointed out, that although two pipes were stopped, not only one to the well, but two others had always been in operation. He allowed their lordships little rest, when, two years after his experiment at Deptford, he teased them into issuing an order, stating that, as the ventilating machine "does not, in *all* respects, come up to the *expectation*, and that the use thereof is dangerous and liable to accidents by fire, yet as he has employed a great deal of pains and time about the invention, for the benefit of the navy, and being desirous to give encouragement to persons who shall turn their thoughts to any inventions that may tend to the advantage of the navy," they gave him a hundred pounds for his loss of time and expenses.

Mr. Sutton accepted the money, exclaiming against the injustice of government for making such a paltry compensation; which he attributed to the ascendancy of Dr. Hales's ventilators in the esteem and regard of some leading persons in the affairs of the navy: had his scheme been perfection itself, he says, it would have been dismissed with an inadequate remuneration.

If he was disappointed in this matter, he was a little while afterwards gratified by his rival's apparatus also falling into disfavour. "That darling scheme," says Mr. Sutton, "is now out of date and exploded. Far be it from me to insult and triumph over a conquered adversary; and it is needless, as well as cruel, to spend much time in confuting a scheme that experience has shown to be absurd and ridiculous. The doctor's ventilators are cumbersome machines and require many hands to work them; mine require no manual labour at all. His ventilators have only a casual and uncertain, mine a certain and uninterrupted effect; his ventilators, he tells us, will keep a prison sweet, mine will sweeten even a ——house; and as my scheme surpasses his in all these respects, so his is dead and buried without any hope of a resurrection, whilst mine rises in its reputation daily."*

The hundred pounds were certainly intended not only to settle the projector's claims for contrivance and labour, but also as a final negative to the introduction of his ventilators into the navy. Mr. Sutton did not choose so to consider it. He was indefatigable, as a one-idea man commonly is, to benefit mankind, with a keen regard, however, to his own advantage: and in spite of their lordships' unfavourable opinion, he began afresh to press the merits of his ventilators upon their notice, and left no stone unturned until he succeeded in having them fixed in several vessels of war; and, when he had succeeded thus far, he was equally industrious in procuring and displaying testimonials in their favour. Among others, Admiral Boscawen, after a long voyage, reported that his squadron and troops were surprisingly healthy, which he partly attributed to the *air pipes* fixed in the ships purifying the air between decks, and he recommended them to be placed on board of men of war in general.

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* Hist. Account, p. 39.

In a few years after this Mr. Sutton had overcome all obstacles and triumphed over all rivals. Inspired by his ruling "patriotic" motive, he tells his steady patron, Dr. Mead, that at last the Navy Board had contracted with him, to fix his engine on board of all ships, whether laid up in ordinary or in commission. "And as I well know," says Mr. Sutton, "the warmth of your heart for the good of our country, *you* will readily concur with *me* in making acknowledgments to these honourable gentlemen in the *name of the public*."

Mr. Sutton was employed for a brief space in fixing his apparatus both in king's ships and in Indiamen. But the naval portion of mankind have at all times been thankless, as well as ungrateful, to improvers. The boon of freedom from infection that he offered to confer upon them, under his patent, for so small a sum as thirty pounds, was refused, and in a year or two no other method of ventilation was known on board ship but the "old way" by windsails.

Notwithstanding this indifference among naval men, both at head quarters and afloat, the fate of the seven line of battle ships sent to blockade the galleons in the ports of Spanish America was still fresh in public memory, and might, perhaps, have prompted a more prudent conduct. Through disease and malaria Admiral Hosier, a brave and experienced seaman, buried his ships' companies twice over; and, instead of coercing the Spaniards, they defied and insulted him. When recounting what he ought to perform with his well-appointed, but nerveless armament, he compared his position and disappointment as its chief to that of a giant, who, at the moment he is about to grasp his antagonist, feels his feet slipping on a heap of quicksand. Yet two years before this calamitous expedition was undertaken, Dr. Desaguliers had shown a way how to purify such a mass of corruption as the atmosphere of the House of Commons, and his blowing wheel was in operation three years before the disastrous expedition to Carthagena covered the country with disgrace and sorrow. No means of ventilation, except windsails, were placed at the disposal of Admiral Vernon, to avert or alleviate any of the mortality that was anticipated from malaria in these pestiferous climates. On that, as on former occasions, the panting mariners saw their comrades in hundreds suffocated with a frowsy stench, with barely strength left to themselves to remove the dead. Windsails were found to be totally useless. Hales also notices their inutility in preventing the scenes that at this time horrified humanity, in the terrible middle passage. Could a highway be formed between the Gulf of Florida and the Gold Coast, it might be covered with the bodies of pagan Africans, murdered by suffocation in Guineamen, and thrown overboard by the christian kidnappers.

The expedition to attack the Spaniards in the Pacific was lying at Spithead, when Hales and Sutton made their experiments in the national arsenal, and established the efficiency of their methods of purifying the air in vessels of war; but Anson's little fleet was allowed to slip their cables, furnished with windsails only. The Centurion, the commodore's ship, had four hundred men on board when she sailed from England; of this gallant band, but two hundred survived when she reached Juan Fernandez, of whom eight only were capable of duty; and had she continued a day or two longer at sea, she must have been without strength to carry her to her anchorage, and have been placed in the situation of the Oriflamma, a Spanish ship, on her passage from Manilla to Acapulco, in which the whole crew had perished from disease, and she was discovered, with all the dead bodies on board, drifting to and fro on the ocean. On one occasion the captains of the squadron represented to Anson that their ships' companies were very sickly, and that it would tend to the preservation of the men to let in more air between decks, but that their ships were so deep they could not possibly open their lower ports; on which the commodore ordered air-scuttles to be cut in each ship, where they would be least weakened. The mortality that these expedients were not sufficient to prevent, was surely a deep reproach on the Government of the day; and the author of the eloquent and affecting narrative of Anson's heroic enterprise remarks, " that if the motives of humanity were insufficient to prompt the preservation of the health and lives of seamen, a regard to the success of our arms, and the honour and interest of each particular commander, should urge, in all quarters, a careful and impartial examination of *every* probable method for keeping a ship's crew in health and vigour. But hath this always been done? Have the late invented plain and obvious methods of keeping our ships sweet and clean, by a constant supply of fresh air, been considered with that candour and temper which the great benefits they promised ought naturally to have inspired? On the contrary, have not these salutary schemes been often treated with neglect and contempt, and have not some of those that have been entrusted with experimenting their effects been guilty of the most indefensible partiality in the accounts they gave of such trials. I own I do not believe this conduct, opposed to the strongest dictates of prudence and humanity, to have arisen from motives so savage as the first reflection thereon does naturally suggest; but I rather impute it to an obstinate and in some degree superstitious attachment to such practices as have been long established, and to a settled contempt and hatred of all kinds of innovation, especially such as are projected by landsmen and persons residing on shore."

Mr. Sutton tried to ventilate buildings on the same principle, and erected his apparatus in two churches, and in a public room, it is said, with much success. While he was engaged on the latter, a catastrophe happened at the Old Bailey, that he attempted to turn to good account.* Urging the lamentable loss of life as produced from the putrid air in the prison, he endeavoured to get a trial made of his ventilator, in one division of the building: and his application was well received by two aldermen, who promised to be his friends on the occasion, and bring the matter before their influential brethren; but no further notice was ever after taken of his proposition or of himself.† Sutton's ventilating labours seem to have been altogether forgotten, when Mr. Adam Walker, a popular lecturer on philosophy, revived the method of thermo-ventilation, without referring to any previous attempts that had been made in the same way. He professed to ventilate, as well as heat a house, without

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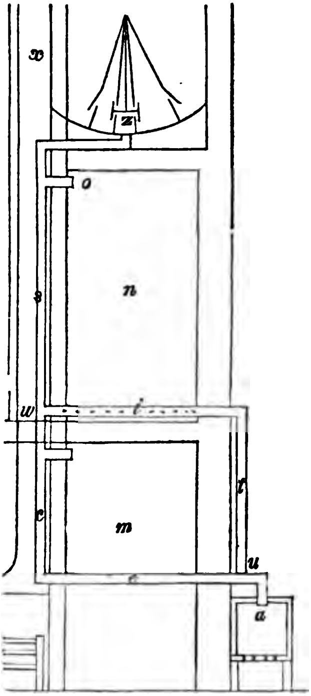
* During the sessions, in 1750, a sickening nauseous smell was experienced by the persons in court, and within a week after, many who had been present were seized with a malignant fever. Among those who died were the Lord Mayor, the two judges, an alderman, a barrister, several of the jury, and forty other persons. It was remarkable that the prisoners, who communicated the infection, were not themselves ill of fever; and it was still more remarkable that none of those who were ill of it, to the greater number of whom it proved mortal, communicated it to their families or attendants, which showed that persons who were treated in clean and airy apartments, as those were who fell victims to it, do not communicate the disease to those in the constant habit of attending to them. —Blaine. Select Dissertations, p. 210.

† Durno. Appendix to Description, p. 5.

FIG. LXXII.



expense, by a kitchen fire, and an apparatus that notwithstanding its economical fallacy is not wanting in ingenuity.

In the Fig. LXXII., *m* represents a part of a kitchen, *n* a room over it; a pipe, *t i*, passes from the box, *a*, through the wall of the house into the kitchen flue, *x*, where it is joined at *w*, to the pipe, *s*, which rises in the flue to the level of the garret floor, where it terminates in the ventilator or triangle, z. A short pipe, *o*, with a valve that opens near the ceiling, is inserted into the pipe, *s*; a pipe, *e c*, connects the pipe *s* with *a*, and a valve is placed at *w*.

If the room, *n*, is to be ventilated only, the valve, *w*, is placed to prevent any communication between the pipes *e* and *i*, and the valve, *o*, is opened. The fresh pure air that enters through the perforations in the bottom of the box, *a*, will rise through the pipe *t*, into the pipe *i*, that is laid behind the skirting, and flow out at the numerous *small holes* made all along its length into the room, to replace the vitiated air that flows through the short pipe, *o*, into the ventilator, z. If the room is to be heated as well as perflated, a valve at *u* prevents the air rising in *t*, and it flows along *e* into *c*, where it "should be heated by the smoke," and the valve, *w*, being regulated to hinder its ascent, the air finds its way into the room through the perforations in the pipe *i*, near the floor, and escapes through *o* into the ventilator at z, but which is used occasionally only when extraordinary ventilation is required, as the usual circulation is produced by the rarefaction in the pipe *s*.*

The ventilator is shown in Fig. LXXIII. Its base is 36 inches long, 12 inches wide, formed circularly, as shown in the figure. On this is fixed the triangle *k*,

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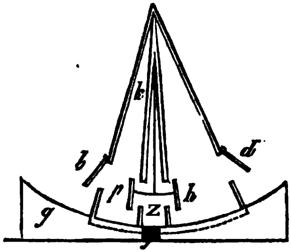
* Philosophical Estimate, p. 34.

33 inches long and 12 inches broad, each side with a hole 2 inches in diameter; from the summit of the triangle a moveable wire, *k*, is suspended, to which two leathern valves, *h*, *p*, are attached.—These hang open when the machine is not in action. The triangular pendulous box, *d b*, is suspended from the summit of the triangle. It is closed every way except at the two valves, *h*, *p*, and at the bottom, which is open, but the lower edges of its ends and sides fit closely, so that when the box vibrates backwards and forwards no air escapes from its interior except through the valves *d*, *b* ; a pipe, z, conducts the air from the pipe, *s*, in the flue, into the triangle. As the suspended box is swung from *d* to *b*, the valve *h* is shut and *p* open, and the valve *b* is shut and *d* open: the air from the pipe, z, flows through the valve, *p*, into the triangular box, and the air on the other side of the triangle flows out at *d* ; when the motion is reversed, the valves *p* and *d* are shut, and *h* and *b* open; the air that had risen from z, now flows through *b* into the atmosphere, and the vitiated air from *g* flows into the side, *h*, into the pendulous box, and so on.*

FIG. LXXIII.



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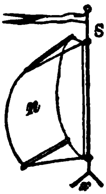
* If, says Mr. Walker, the gentle reader's curiosity is excited to know what is the use of the box, *a*, (in Fig. LXXII.) since the pipe might have opened at once to the atmosphere. " he may be told that it is to contain certain ingredients for purifying the

The mortality and disease that Mr. Howard found prevailing in every prison of the kingdom were attempted to be removed in 1775, by empowering the magistrates to order the ceilings and walls of such buildings to be "scraped and whitewashed once a

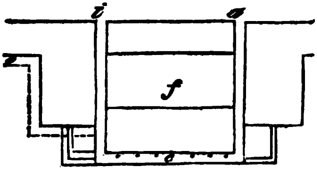
FIG. LXXIV.



air, which are principally what nature uses for the same purpose, but they are too cheap to be objected to by any one, and I hope," he says, "that the world will not think me churlish in concealing this part, or in the measures now taking to secure an exclusive right in the disposal of them." What the purifying ingredients were he did not disclose, but he said that boxes of aromatics and perfumes, or roses might be used instead. He thought his ventilators might be moved by the wind, if a sail, *n*, Fig. LXXIV. were rigged to a mast, S, and fixed at *x*, to the pendulous box. "As the wind is by intervals less and less, so it will affect the sail, and make the mast nod a motion which will make the pendulous box move to and fro, as if it were done by hand."

In the case of a defective supply of air to the fire from the close finishing of rooms and windows, Mr. Walker suggested the use of a *hollow fender*. Two holes, Fig. LXXV. *a*, *i*, were made through the wall at the corners of the hearth, *f*, in which he fixed tubes 4½ inches by 2½ inches in the clear, and as long as to reach to the face of the jamb, or to the front of the fender, *c*. The fender was made hollow, and perforated with small holes along its inner face, near the top, in front of the fire. Two openings were made at the bottom of the fender for it to slide on these pipes about an inch where they came through the wall. This formed a communication with the external air, which flowed through the perforations on the fire "in the most friendly direction possible, without giving cold or offending any person in the room."

FIG LXXV.



Should the chimney be in an inner wall, or join a neighbouring house, the air pipe may be conveyed behind the skirting to the fender from the outside; or where the room is over a cellar, a hole is to be cut through the hearth in which a *metallic cullender* is to be placed to divide the stream of air, so that it shall rise in the most favourable way into the fire, as well as prevent the cinders falling into the air channel.—Phil. Estimate, p. 23.

year at least, and supplied with fresh air by hand ventilators or otherwise," because, as the act expresses it, "the malignant fever, commonly called the gaol distemper, is owing to a want of cleanliness and fresh air." These hand ventilators are not described. If not large fans, they were probably some variety of Dr. Hales's ship's lungs. Their occasional use only seems to have been enjoined.

The philanthropist's benevolent suggestions on the subject of ventilation were confined to relieving the morbid effects of foul air by apertures made in or near the ceiling of each room, through which the breathed air might escape and fresh air enter; and by an improved method of hanging the sash on a pivot, so as to have, when open, a slanting direction upwards, in order to turn the entering current of fresh air towards the ceiling, but without any view to its regulation as to temperature or quantity.

These contrivances were seldom effectual. Other methods were tried, and occasional fumigations, as heretofore, were considered more efficacious in neutralising the effect of putrid air than the introduction of pure air by windows and tunnels. The improvements recommended by Mr. Howard had been introduced into the prison at Maidstone, but it continued to be infested with pestilential fever, until its surgeon hit on a method of purification, which effectually eradicated the contagion for a period. An account of his process was sent to every prison in the kingdom, and it may therefore be considered a favourable specimen of the most popular method of ventilating such places at this period.

To exhaust a ward of foul air, Mr. Day "preferred the method of rarefaction by boiling lime, and boiling vinegar alternately used, to hand ventilators." It was thought necessary to wash and scrape the walls of the cells, and before the fumigation, to have every aperture communicating with the internal part of the prison, closely shut, while all the openings next the external side were left open; that as the foul air was rarefied, and passed out at the upper part of the openings, fresh air might be admitted at the lower part. Mr. Day then took of rue, wormwood, sage, lavender, mint and rosemary, each a handful, and put them altogether into a gallon of the best vinegar, and let it boil, and while boiling, threw it on the ceiling and walls, and all parts of the room, by a garden engine, that had a fan or rose to divide the liquor into small streams. After which, the room was well dried with a brasier, while the window next the external air was open, and all the other apertures shut; a little camphor burning in a fire-shovel, being carried into it, the operation was finished.* When it was required to operate on the air only, Mr. Day altered his garden engine to pump up boiling lime water into a small reservoir that had a perforated bottom, through which the water fell in showers into the trough, as long as the pumping was continued; and during the operation, the machine was wheeled to the different parts of the room, that the shower might pass through as much of the confined air as possible; and over each bed, and such parts as it could not be wheeled to, a man was directed to force away by a large fan, the air of such spots towards the purifier, "to make room for that which had been corrected."

This machine was used daily in the building, and so refreshing, says Mr. Day, were the showers of lime-water, that all declared the effect resembled the earth being cooled, in a sultry hot day, by a hasty shower of rain; and from a strict observance of these methods of fumigation, washing the walls and ceilings with boiling lime, throwing quicklime from time to time down the necessaries and along the drains, frequently changing the linen and clothes, having a constant attention to cleanliness, and washing the men daily with warm suds, and drying their clothes every week upon an oast with sulphur, and giving them nutritive food, the contagion, says the surgeon, was totally eradicated. But, in spite of this successful result, he had misgivings about the specific virtue of some of his disinfectants. "I am very doubtful," he says, "with regard to many substances, burning either in flame or smoke, whether they have any effect further than as being instrumental in forcing out foul and letting in fresh air, and therefore, if proper attention be not paid to the shutting and opening of the different openings, these fumigations are in a great measure of no effect, and render the included air more unfit for respiration."* Yet with this impression, which must have been that of the profession generally, no attempt was made in any quarter to obtain the effect of all these laborious and expensive operations by the simpler and more effective process of Desaguliers and Sutton.

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* Some Considerations on Removing Infectious Airs, p. 50.

St. Thomas's Hospital was ventilated by Mr. Whitehurst, of Derby, some time about 1784. In every second window, about an inch and a half of each pane in the bottom of the upper sash was cut away. A frame of glass, nearly two feet in width, was set across the window, resting upon the top of the lower sash, and fastened to it by hinges. The frame moved on the hinges, so as to make a greater or less angle with the window, and by that means admitted more or less air at pleasure; and the air which entered between the sashes was directed by the frame toward the ceiling, and diffused through the rooms without any perceptible current.†

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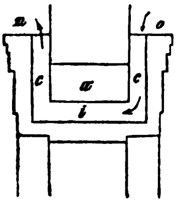
* Considerations, &c., p. 56.

† Observations on the Ventilation of Rooms, p. 21.

Among the devices that he recommended for admitting air into rooms where it was not convenient to make perforations in the walls, three may be noticed.

FIG. LXXVI.



The first was, introducing the air between the folding of the sash frames, by cutting away about an eighth of an inch from the frame, and leaving the whole substance at each style. Raising the sash five or six inches above the sill, and applying a board at the same distance to direct the stream of air towards the ceiling. Or he left an open space, *c*, between the upper part of the architrave, *o n*, (as in Fig. LXXVI.) surrounding the door and the wall, on each side, and likewise an open space between the casing and the lintel. The air then descended in the space between the architrave and the wall on the outside of the door, and ascended between the architrave and the wall on the inside, in a perpendicular direction.

About 1785, a ventilating contrivance, borrowed from a French frigate, began to be introduced into English vessels of war.* It consisted simply of square wooden

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* Blaine on Diseases of Seamen, p. 266.

Some of the good effects this helped to produce is apparent from a reference to the health of the navy before its introduction. In 1779, 70,000 seamen and marines were voted by Parliament; of these 28,592 were sent sick to the hospitals, or 1 in every 2·4. In 1784, of 85,000 men afloat, 21,371 were sent ashore sick within the year, or 1 in 4. But in 1804, when perhaps the ventilators were formed in most of the ships, of the 100,000 men of which the navy that year consisted, 11,978 passed through the hospital, or 1 only in 8·3. A still more extraordinary example of the effect of improvement in naval ventilation is afforded by the Glatton, a transport, equal in tonnage to a sixty-four gun ship, that was ventilated under the direction of Count Rumford and Sir Gilbert Blaine. Air tubes, like those which have been described, passed from the places where the prisoners were to sleep, alongside of the ship to the open air; and a narrow opening amidships, the whole length of the upper deck, protected by a covering, in form of a pent-house, a few inches above it, to prevent rain or other things from falling into it; and scuttles were made in the sides to open and shut according to the weather. She sailed from Portsmouth on the 23d of September, with 400 prisoners, besides 31 women and children, and a ship's crew of 170 men—in all 601 souls on board, and trunks (for which brass tubes were afterwards substituted), running from the hold or lower deck, and terminating in the open air. The great importance of these will be obvious, when it is recollected that in this deck there is neither hatchway nor ladder, and that the sleeping places are under it.

Among the improvements made in the Bank of England, a novel sort of stove attracted much attention. One was placed in the centre of the hall, and one in each of the principal offices. They diffused a gentle heat, and great curiosity was excited respecting the means by which it was produced. No fire was visible, and as there was no appearance of chimney or flue, it was conjectured that the smoke was consumed within the small domes with which each of the stoves was terminated, or that the element was fed with some material which could undergo combustion without emitting noxious vapour. It was, however, a modification of the German stove, now called the hall stove, in which the draft was downward, and the smoke conducted under the floor. Though much admired for its elegance and ingenuity, loud complaints were made, that the warmth emitted from the surface of the cast iron was unwholesome, and that the air of the room was not changed and purified as it would be by a common fire, and that it produced

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she passed Portsmouth on the 22d of September, 1803, in proceeding up the Channel to the Downs, having circumnavigated the world in 364 days, without losing a single sailor, or touching at any port for seventeen weeks and five days in her homeward voyage.

About 1796, fire-places of cast iron were substituted for those of brickwork, as formerly constructed. It was long after this that Sir Robert Sappings introduced his improvement of obliterating the cavities under the floor of the hold, which used to be the receptacles of filth, and all manner of vermin, dead or alive, proving perpetual sources of foul air, and of offensive and noxious exhalations. He also left intervals between the timbers of the frame, to maintain a constant communication between the open air and the hold, and spaces between the decks. A more recent improvement, although a very simple one, has had much influence on the purity of the air. This is the illuminators, or *bull's eyes*—thick spherical portions of glass inserted in the ports and decks, for the admission of light in bad weather, when all the inlets of light and air are barred up. They supersede the use of candles in the day-time, which tend to contaminate rapidly the air already too close and foul.

disorders in the lungs, and had generated a new disorder, or the *iron cough.*[*] These stoves were removed in 1787, and their places supplied with others which had their fireplaces open. In the discarded "hawk and hem stove," the air was heated on the external surface only, which never was raised to a visible heat; in the new apparatus two stoves were placed back to back, and a case of meanders, which must have been always white hot, was set between them, into which the cold air, drawn from a crypt beneath the pavement, was admitted, and flowed through openings in its sides, into the hall. The *sight* of the fire, however, was so salutary, that the roasted air which was emitted from the stove in copious streams, so abated the symptoms, that the iron cough, under the steady exhibition of this medicine, finally disappeared!

Although a trifling improvement only was made in existing buildings by the introduction of air channels, Mr. Howard's suggestions determined the principles which were followed in the erection of new places of confinement. In these it was endeavoured, by a structural arrangement, to facilitate the passage of air through them in straight lines, from one extremity to the other, and its free passage into and through every apartment. With this view, the rooms were placed on one or both sides of a gallery which was open at each end: an aperture made in the wall near the ceiling of each room, opened at right angles into this long passage, and a similar aperture was made in the opposite wall from the room into the air. In this arrangement there was no obstruction to the freedom of the atmospheric current, and it was thought the air moving with greater velocity through the long passages, would of necessity carry along with it the weaker currents, passing at right angles from the rooms. After a trial for nine years in a prison, in which 1,300 persons had been confined, and during which there occurred three very severe winters, the mortality was reduced under the average of that of the district. Sir George Paul therefore concluded, that in a room in which there was no fire, having from 52 to 57 superficial feet of floor, and containing from 415 to 439 cubic feet of air, and built with brick and arched over, so that no air could enter but through openings provided for it, and ventilated by opposite apertures near the crown of the arch, and a window made so as not to close accurately, the body of a person sleeping under a proper allowance of woollen bed-clothes, will so far warm the atmosphere around him, or so little of the heat generated in his body will be carried off by the surrounding air, that he will not suffer by a current passing at a distance over him, provided the apartment be free from damp. The thermometer was never observed to be below 38° in the middle region of a cell in which a prisoner was sleeping, whereas in the ordinary apartments of a dwelling house, water frequently freezes by the bed-side; and Sir George thought that, as far as regards warmth and ventilation in such cases, nothing further was to be desired.*

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[*] Gentleman's Magazine, vol. lviii. p. 209.

But in this way of looking at the matter, the brick walls, and ceiling, and door, and window might have been altogether excluded from consideration—for, with "a proper allowance of bed-clothes," a person may sleep on the snow in the open air, or, like the inhabitants of the polar regions, in a room with the walls and ceilings formed of blocks of ice, with the air at a temperature under zero.

There seems, however, reason to suspect some fallacy in the indications of his thermometer, or that the ventilation was not so perfect as he thought it was;

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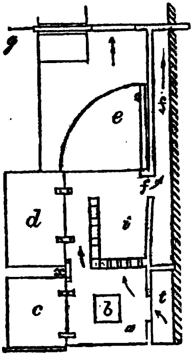
* Repertory of Arts, vol. ii. p. 268.

for it is not easy to imagine how a room, freely communicating with the external air, could have a minimum temperature of 38°. And a modern physician might also consider the ultimate effect on the constitution of an inhabitant of Sir George's beau-ideal sleeping room not to be quite so salutary as he stated it.

The free ventilation, or the transverse passage of outward air, that satisfied Sir George in the sleeping room, he admitted to be inconsistent with the general warmth required in rooms occupied by the sick, and in all day rooms for the healthy, in cold weather. He also found, that channels in the ceiling or walls for the escape of foul air, unassisted by a power more constant and decisive than the relative specific lightness of that air, was not sufficient to preserve a healthful respiration in the crowded wards of an hospital; and he therefore accelerated the draft, or determination of air to the ceiling, by an increased degree of rarefaction, produced by means of a fire.

The method Sir George recommended and practised was the same as that followed by Mr. Sutton. An air-tight channel or funnel was made in or near the ceiling of the room to be ventilated; this tunnel was brought to terminate in the ashpit, immediately under a fire in a grate so enclosed that no air from the room in which it is placed, could enter it.

FIG. LXXVII.

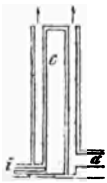


It is shown in Fig. LXXVII. in which *a* is the ashpit, *b*, an opening leading into it from the channel in the ceiling of the room that is ventilated; *c*, a door enclosing the ashpit; *d*, another door in front of the fire-box, and *e*, a cover enclosing the upper surface of the fire; *f*, an opening for the smoke, when the doors and cover are shut; and *g*, a damper closing up the flue of the chimney towards the room, and opening that between the aperture, *f*, and the flue. When this apparatus was used as a ventilator, the doors, *c*, *d*, and cover, *e*, were shut, and also the damper, *g*. The air therefore flowed from the aperture in the ceiling of the room into the channel that led it through the opening, *b*, into the ashpit, to supply the fire, and it passed through the smoke opening, *f*, into the flue of the chimney.

The ward of the hospital over which Sir George fixed his apparatus, contained 18,000 cubic feet of space, and was filled with patients, and which, in spite of all former means, had always been remarkably offensive, was in a few minutes perfectly relieved of contaminated effluvia, without any increased current being perceptible.[*]

It was about this time, perhaps, that Mr. William

FIG. LXXVIII.



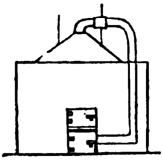
[*] Mr. Green, who in 1793 had a patent for warming rooms, sometimes ventilated them in the same way, but substituting steam instead of fire; he placed a pipe, *c*, 9 inches in diameter, and 5 feet high, in another pipe about 13 inches in diameter. The inner pipe was filled with steam; and the outer case was open at the upper end. A pipe 2½ inches in diameter was inserted into the side of the outer pipe and near its base, and its other extremity opened to the ceiling of the room below. The rarefaction in the concentric space was sufficient to produce an agreeable change of air in a dining room 25 feet long, and 17 feet wide. This apparatus was in occasional use for 16 years.

In 1802, Mr. Salmon cleared places of noxious exhalations by fixing an air-tight metallic tube, about 1½ inch in diameter, to the uppermost part of the room or vault to be ventilated, and carried this pipe to the kitchen or parlour fire, and joined it to the end of a series of caliducts made in the back of the grate, as described by Cardinal Polignac, from which it was conducted by a tube into the air, or into the chimney. This, which is the same as some preceding schemes, Mr. Salmon secured to himself by a patent.—Repertory of Arts, vol. i. p. 162.

Strutt, of Derby, revived the method invented by Mr. Evelyn, in which the natural method of ventilation was inverted. He admitted the fresh air at the ceiling, and the vitiated air was drawn off at the floor, but by what particular means has not been stated.

This ventilation by descent, has been noticed by a competent authority as being a " noxious fallacy. The mephitic exhalations from our lungs, having a temperature of 98°, rise and occupy the upper part of the room,

FIG. LXXIX.



In 1820, Mr. London adapted Sir George's method to destroy the offensive effluvia produced in some manufacturing processes, such as soap-boiling and tallow-melting. The boiler was set in the usual manner, and the ashpit of the fireplace was formed to be perfectly closed. The lid of the boiler fitted very tight, and a pipe which rose from it was carried into a channel that opened into the ashpit; as the fœtid exhalations evaporated from the matters in the boiler, they were conducted by the pipe in the lid, into the channel and ashpit, and through the fire into the smoke flue. The room in which the most offensive process was going on, was free from smell, and by the same simple and easy means the neighbourhood was delivered from what had been an intolerable nuisance.

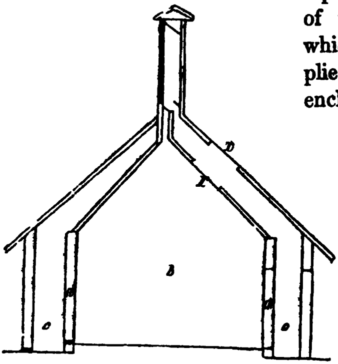
By the same method of rarefaction, Mr. Tyers, in 1821, purified some wards in Hackney workhouse that had been long most obnoxious from stagnant vapours.

A few years ago, some small houses near Glasgow were ventilated in a similar way. A long building that served for dwelling houses for 500 workpeople, was ever dirty and ill-ventilated, and frequently visited with fever in its most fatal type. Along the ceiling of the corridor, which runs the whole length of the building, and on one side of which the entrance doors to the lodgings are placed, Mr. Fleming placed a large iron tube, shut at one end, and open on the other, where there was a valve, at its connection, with the great chimney shaft of the mill. From the side of this horizontal pipe, opposite to each apartment, a tin tube, 1⅛ inch in diameter, branched off at a right angle, and entered through the wall, so as to present its open end immediately over the bedstead of each room. Whenever the steam-engine was stopped, either at meal hours or at night, the mechanism which shut the fire damper was so constructed as to open at the same instant the valve at the inner end of the corridor pipe, whereupon a brisk current was established in each tube in each room, and a stream of air rushed from every apartment into the chimney. Since the introduction of this powerful system of ventilation, the factory houses have been free from pestilential fever.—Ure. Philosophy of Manufactures, p. 394.

and, if forced downwards by any means, must inevitably be breathed again and again by the inmates, before their particles can be discharged at the level of their legs and feet, in defiance of the laws of specific gravity;"* and this opinion accords with every theoretic deduction; yet Mr. Strutt's anomalous method in practice preserves an agreeable and salubrious atmosphere, and the heat is even more equably diffused than with an upward current. On the small scale, in which only we have seen it, it appeared, notwithstanding the cogent reasons against its principle, to be, in many cases, the preferable mode; particularly where dust was reckoned an annoyance.

Instead of the rarefaction of the air being produced by a fire, as in the preceding examples, Dr. Anderson, in 1800, described a method to ventilate, through summer and winter, by the sun's heat only.

FIG. LXXX.



The Fig. LXXX. represents a section of the building to which the doctor applied it. *a*, a wall enclosing an inner room, *b*, has an aperture or air-hole, in each of the sides, placed a few inches above the floor, and fitted with a valve to close or open it at pleasure; *c*, a passage continued round the inner room, from 4 to

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* Architectural Magazine, vol. v. p. 33.

6 feet wide, with its floor 12 inches lower than that of the inner room, and a few inches above the level of the ground. The external wall enclosing the passage, has an air hole made in its north side under the threshold, fitted with a valve. The entrance to this space is by a door, *s*, in the north wall, and opposite the door, *f*, to the inner room, as shown in Fig. LXXXI., which is a ground plan of the dairy. Another door, to the passage, made from the anteroom, *k*, is to be used in winter, when the external door is kept closed.

The outer roof is slated or tiled, and the inner roof formed of lath and plaster, and both are to be made perfectly air tight. The window in the inner roof, and that over it in the outer roof, are fixed and also made air tight. The space between the roofs gradually diminishes till it terminates in the wooden chimney or ventilator, *l*. This pipe on three sides is made of wood coated with plaster; the fourth side, placed towards the south, is of glass, puttied so as to be air tight. It is a parallelogram, having the widest side from east to west. Its widest side may be 2 feet, its height not less than 6 feet; the higher it is its effect will be greater. Fig. LXXXII. shows it in section on a larger scale. It has a valve, *m*, near the top of the tube, which

FIG. LXXXI.

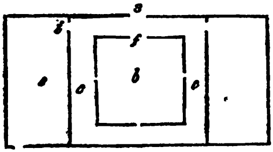
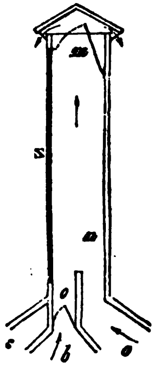


FIG. LXXXII.



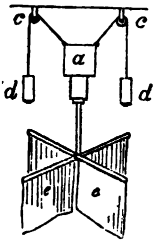
shuts out the external air; another valve is placed at *n*, and opens or shuts the communication between the inner room, and the ventilator and passage; the valve, *o*, closes the way between the ventilator and the room. The ventilator is covered with boards, to prevent the entrance of rain, and the air escapes at its eaves.

When the sun shines on the glass, it heats the inside of the tube along its whole length, which warming the air within it, gives it a tendency to ascend, with a velocity proportioned to the length of the tube, and the difference of temperature between the air within and without. If the valve, *m*, be open, this heated air will rise through the holes made under the eaves of the ventilating tube, and an upward current from below will then be produced. When the valve, *o*, is raised, and the opposite valve closed, the air rises from the inner room only, and is replaced by the fresh air from the passage, flowing through the air channels near its floor; and if the valve, *o*, is closed, and the other open, the ventilation takes place in the passage only, and the external air enters by the air-hole under the threshold. If the valves, *o* and *m*, be closed at the same time, no ventilation can take place from below, but a circulation will go on in the passage, while the air in the inner room will be in a state of repose.

In summer, the valve, *n*, will be generally open, and the valve, *o*, shut, to let the air heated in the passage escape; but in winter, the valve, *n*, will be generally closed to retain it, by which means the temperature is equalized. In the day-time, during winter, the valve, *m*, is kept shut, and *n* is open; then there is a circulation of the warmed air in the tube, which extends to the air in the passage.*

By a similar method, cellars, vaults, and confined rooms might be ventilated at a trifling expense in all seasons. The ventilating pipe, says the ingenious doctor, may be carried up on the outside of the south wall, and attached to it so as to be made of considerable breadth and height, without being liable to accidents from winds. From the vault, or cellar, to be perflated, a pipe or funnel may be carried into this glazed area, and a constant current of air would flow from them through the ventilator.†

FIG. LXXXIII.



The Zephyr was an elegant contrivance by Mr. Dobson, to prevent the air stagnating in any part of a room; and was particularly adapted for removing, in a sick chamber, the air that might incommode the invalid, or refresh him by a breeze, moderated so as to be grateful to his feelings. It is shown in Fig. LXXXIII. The case, *a*, contains a mechanism like that of a bottle-jack, and is suspended from the ceiling by two lines passing over the pullies, *c*, *c*, and balanced by the weights, *d*, *d*. It may thus be raised to, or drawn down from, the ceiling. The sails, *e*, *e*, are attached to the mechanism, and revolve in a horizontal direction at any height at which it may be adjusted.*

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* Recreations in Agriculture, vol. iii. p. 409.

† The warmth as well as the ventilation of rooms might also be augmented by this contrivance. The whole south front of the house is to be covered with glass, at any convenient distance from the wall, and made so as to exclude all air, except by the openings placed beneath to admit it. In winter, during sunshine, the valve, *m*, being closed, the air between the glass and the wall will be much heated, and if passages with regulating valves open into the rooms from the

Count Rumford, however, in general was more studious to make the heating process perfect, than the perflating one. Indeed he may be said to have undervalued specific ventilation. "Though a room be closed," he says, "in the most perfect manner possible, yet the quantity of air injured and rendered unfit for further use, by the respiration of two or three persons in a few hours, is very small, compared to the immense volume of air which a room of moderate size contains; and as so much fresh air always enters the room, and so much of the warm air is drawn out of it every time the door is opened, there is much less danger of the air of a room being unwholesome, for the want of ventilation, than has been generally imagined, particularly in cold weather, when all the different causes, which conspire to change the air of warmed rooms, act with increased power and effect. In consequence of the air being equally warm all over the room, (from the use of his improved fireplaces,) it may be completely changed with the greatest facility, and the room completely ventilated, when this air is become unfit for respiration, merely by throwing open for

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glazed area, they will have their temperature considerably raised. To distribute the air that may be heated, the glazed area may have a horizontal partition at each floor—and while it was performing this service it might be employed with the best effect as a vinery.—Ibid. vol. iii. p. 410.

The effect of the ventilator, even in the winter, would be considerable. When the maximum temperature in the shade for the day, in February, was 54°, a thermometer placed against a south wall rose to 87°; and in another experiment, also, in February, a thermometer, placed in a small cavity of a garden wall, with a south aspect, stood at 70°; in the shade of the house, at 42°; and on the ground, at 32°.—(Howard. The Climate of London, vol. iii. p. 140.) In the warmest weather, when motion in the air is particularly desirable, it might in this way be produced with great effect. A thermometer, placed in an apartment opening into a garden, stood in July at 68°; in the sun, it rose to 120°. With any of these differences of temperature, the Solar ventilator would produce a brisk continuous wind.

* Repertory of Arts, vol. ii. p. 405.

a moment a door opening into some passage, from whence fresh air may be had; the upper part of a window; or by opening the upper part of one window, and the lower part of another. As long as any fire is kept up in the room, there is so considerable a current up the chimney, notwithstanding all the reduction that can be made in the size of its throat, that the continual change of air which this current occasions, will be found quite sufficient for keeping the room sweet and wholesome."* And, he adds, that "even in rooms in which there is no fireplace, and consequently no current of air open from the room setting up the chimney, as is the case in Germany, and in most of the rooms abroad which are heated by stoves, the windows and doors are double, and both are closed in the most exact manner possible by slips of paper pasted over the crevices, or by slips of list or fur; yet when these rooms are tolerably large, and when they are not very much crowded by company, nor filled with a great many burning lamps and candles, the air in them is seldom so much injured as to become unwholesome; and those who inhabit them suffer no inconvenience from their closeness." But, with his usual candour, the Count adds, that "there is frequently, it is true, an *oppressiveness* in the air of a room heated by a German stove, of which those who are not much accustomed to living in those rooms seldom fail to complain, and indeed with much reason; but this does not arise from the air of the room being injured by the respiration and perspiration of those who inhabit it, but from some part of the stove in contact with the air of the room, *roasting* the dust which falls on it."

The decomposition of the dust is, however, one only of the many causes that modern chemists show deteriorate the air of inhabited rooms; and although the Count's notions of the effect of certain agencies were erroneous, and his method of opening a door or window, *occasionally*, to produce ventilation, would, in modern practice, be held to be barbarous, and inefficient; yet his singular opinions on one point cannot weaken his deservedly great authority on other questions connected with the economy of heat. He did attempt, now and then, to practise a more perfect method than he taught. Two rooms in his house were ventilated by a pipe that had an area of 3 inches by 2 inches, inserted near the cornice into the smoke flue, and it was furnished with a small sliding valve to open or shut it. One of the rooms was heated by a German stove set in the hearth recess. It had a false back, fixed at a distance of 2 inches from the stove back, forming a space enclosed at the sides and open at top and bottom. Into this space, air was admitted from beneath the floor, and rising between the false backs, was somewhat warmed when it entered the room. The ventilating pipes and false back were afterwards removed, and the air to supply the ventilation was drawn from the space between the *double* windows of both rooms.

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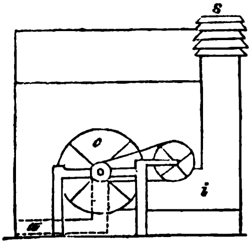
* Essays, Political, Economical, and Physical, vol. i. p. 302.

The wheel described in page 41, continued to ventilate the House of Commons until 1791, when it was moved into another position over the centre of the house, the better to perform its office. A view of this classical machine is given in Fig. LXXXIV.*

FIG. LXXXIV.



It would seem that at this time the members were annoyed with cold which did not depend on the ventilator, and with an accumulation of heat, which did. On the advice of Mr. Walker, whose project has been described in a preceding page, a large stove, 6 feet on the side, and 14 feet high, and filled with earthen pipes and retorts, was placed under the floor, and the air warmed in moving through them, entered the house at a grated aperture 3 feet in diameter made in the floor. To improve the ventilation, two chimneys with cowls were placed on the roof; and of these it may be observed, that being unconnected with the centrifugal ventilator, their effect was to render its otherwise effective operation nearly useless.

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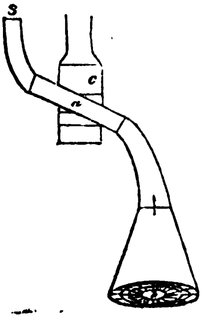
* Richardson. Treatise on Warming, &c. p. 104.

The House of Lords also was not sufficiently warmed by the flues built under the floor, and its ventilation had always been very imperfect. Sir Humphry Davy conveyed fresh air through brick flues, built alongside, and attached to the heating flues, and the air warmed by these means he admitted into the house by small perforations in the floor, the exact number of which, as well as the fee for advice, is recorded in two lines of an epigram written on that occasion—

"For boring twenty thousand holes,
The lords gave nothing—damn their souls.
For——"

FIG. LXXXV.



The temperature of the air flowing through them, he increased or diminished by regulating the furnace.

To remove the vitiated air, Sir Humphry placed a metallic tube *a S*, Fig. LXXXV., over each of the two openings in the ceiling. A portion of this tube was heated, by passing through a fire, *c*, and the rarefaction created was sufficient to produce a current to carry off the impure atmosphere from the house beneath, at the aperture, *c*, which was connected to a cowl placed on the roof. It was not, however, always found effectual; and when the house was crowded, the air would rise to 80°, and the smoke sometimes get into the house through the ventilating tube.

To ascertain the cause of this, and discharge what he considered to be his duty, the architect had the courage " to put his head over the ventilation pipe when the fire was at full heat, but did not perceive the hot air coming from the house;" and in his report, he tells their lordships, that he performed the same feat " at other times without fire, and found a very strong current of hot air from the body of the house;" his official reverence for their lordships, not allowing him to describe what were his sensations on the last occasion. We estimated the benefits produced by Sir Humphry's ventilator to be much greater than the architect did, from our happening once by accident to approach within a few feet of the cowl, when the fire was at its ordinary heat, and the house not crowded. The whiff we had of the gaseous evacuation caused the only indelible impression ever made on our olfactory organs, although they cannot boast of any particular sensibility—after a lapse of thirty years the recollection of it is as pungent as ever.

Notwithstanding that Mr. Lee didnot find the ventilator at all times produce an upward current, it is certain it could not cool any hot air that did ascend, and therefore, when his head was in the cowl, a current of fresh air most likely set downward, through the wide ventilator into the house; a circumstance that will occasionally happen where the doors and windows are placed like those in the old House of Lords, and the persons who have the care of them are equally careless and idle. To remedy the defects, the architect enlarged the 12 inch pipes to 3 feet, and furnished them with a valve to prevent the entrance of cold air. The fire ventilator he considered to be unnecessary. This alteration greatly increased the defect of the apparatus, and it was found less adequate to sweeten the Lords than before. The architect's proposal to draw the air from *his* bungled ventilators, by a wheel like that over the Commons, was not acceded to. That, however, shows, that Dr. Desagulier's mechanism, after being in use for 74 years, still answered its purpose.

In the Infirmary at Derby, Mr. Strutt introduced the fresh air by a culvert, having an area of four square feet, which extended 210 feet from the building. At its extremity he placed a vertical funnel terminated by a vaned cowl or turncap, that kept its mouth constantly *towards* the wind. On the top of the building there was another funnel with a similar turncap, that kept its mouth *from* the wind; into this he conducted all the channels for carrying off the foul air of the wards; and a flue or air duct was carried from the upper part of the stove into each floor of the building. The fresh air that entered the underground tunnel, being made to impinge on the heated surface of the stove, was warmed and thence conveyed through the air ducts to each floor, and as it entered the rooms the foul air was expelled at the openings near the ceiling into the channels or tubes that opened into the upper funnel, from which it was emitted at the vaned cowl into the atmosphere.

The underground tunnel being at some depth below the surface, its temperature was near the mean of that of the climate. In the winter weather the air in the tunnel was warmer than the air without, and in summer it was colder. In August, when the thermometer in the shade stood at 80°, the air that had flowed through the funnel had a temperature of 60°, which was admitted by the air ducts to temperate the atmosphere of the different apartments.*

About 1810, the Hunterian Museum was ventilated and warmed on nearly the same plan. The great improver of the steam engine, we believe, revised the drawings of the apparatus that were made by Messrs. Boulton and Watt, by one of whose engineers it was erected. The climate produced was most genial and pleasant. Some large factories and an observatory were in the following year heated and ventilated by Mr. Buchanan, on the Soho model. After a trial of six years the apparatus was stated to have given great satisfaction, and not to have required any repairs. Mr. Buchanan, however, thought that the heating and ventilating processes should be kept distinct, so that each could be managed separately, and no more heat nor ventilation given than what was just proper, which he considered could not be done by a hot air apparatus.† But this opinion is not strengthened by longer experience, for in what now appears to be the best practice the processes are combined.

The use of hot water as a ventilating agent was introduced by Mr. Deacon in 1813. He drew the air from an underground tunnel or from a cellar by means of a fan, and forced it through small iron or earthenware tubes, placed in boiling water, into the rooms, and conducted the vitiated air into a tube or channel at the ceiling, which was carried above the roof where practicable. Instead of pipes, Mr. Deacon occasionally used *iron plates* parallel to each other, leaving a space of about 1½ inch between them. These were placed in boiling water, and the air rose in the space between the hot plates. In warm weather, when it was desirable to cool the apartments, Mr. Deacon immersed the pipes or the plates in cold water, and threw the air that was cooled by passing between them into the rooms by the fanner. Where the room was large the fan was moved by a man, but in common cases it was kept in motion by the unbending of a spring or fall of a weight. Mr. Deacon fixed his "Eolian" apparatus in some public buildings; but, although possessed of great practical merit, and wholesome, besides, in its effect, and safe in its application, it failed to bring the merited reward to the inventor.

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* Sylvester. Philosophy of Domestic Economy, p. 20.

† A Treatise on the Economy of Fuel, p. 302.

A year or two later Mr. Sylvester made many ingenious applications of Mr. Strutt's method to private as well as to public buildings. In the Lunatic Asylum at Wakefield he heated the galleries by warm air generated in the same way as at Derby. The sleeping rooms opened into the galleries, and he made a hole in the door of each room, by which means they were kept at the same temperature as the passage. From the floor of each bed-room a flue was carried to the roof of the building, and each flue had an opening at the floor and another at the ceiling; the lower one to be kept open in the winter, and the upper one in summer, to accelerate ventilation. When the heating apparatus was in action, the whole air of the building, equal to 400,000 cubic feet, was changed every hour. In one or two instances, where the perflating process was not so perfect as was desired, the failure arose more from the peculiar construction of the building and carelessness of those to whom the management of the apparatus was entrusted, than from any defect in the method or want of skill in its adaptation.

The Marquis of Chabannes was an earnest and successful candidate for smoke-doctor distinction.

"In January, 1814, while I was writing," he says, "the whole day in London, before a very large fire, burnt on one side and frozen on the other, by the current of cold air rushing into the room, by every aperture, to supply the draught of the fire, I felt more sensibly than ever the great defects in the present construction of stoves; and in this situation I first conceived the plan of the calorifere, and had a model executed with the intention of having some stoves made, and taking them with me into France for my own use, when an order from the king obliged me to depart early in February for Flanders. Sorrow and affliction induced me to quit France soon after the installation of the king, and I returned to England weeping over the destiny of the House of Bourbon, and the future miseries of my too unhappy country. I then had a calorifere stove made with the sole design of guarding myself from cold, but the importance of the invention appeared to me so great, from the equal and agreeable warmth I experienced in every part of my apartment, that I resolved to take out a patent for it, and make public my long meditated plan for regulating the temperature, and conducting and purifying the air in our dwellings; and my chief aim in this was the ambition of being known as the author of *forced ventilation*." *

The apparatus produced in these interesting circumstances, is shown in Fig. LXXXVI. in a front view, and in Fig. LXXXVII. in section. The stove is fitted in the usual way into the hearth recess; *a* is the fuel grate surrounded on the sides and back with insulated iron tubes, *c*, opening at their lower end into an iron air box, *d*, and into a similar iron box, *e*, at their upper extremity. In the top or side of each of these air boxes is an aperture, *g m*, and the smoke escapes into the flue at *h*, as in other grates. At the opening, *g*, in the lower air box, is a communication by a pipe

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* On Conducting Air by Forced Ventilation, p. vi.

FIG. LXXXVI.

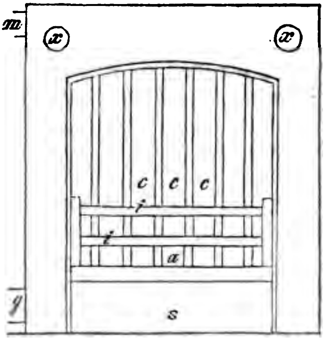
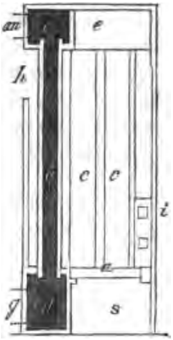
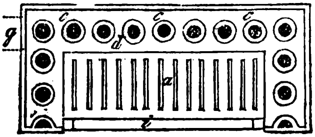


FIG. LXXXVII.



or channel with the ceiling of the room to be ventilated; and by the aperture, *m*, in the upper air box, a communication is made with the open air. The

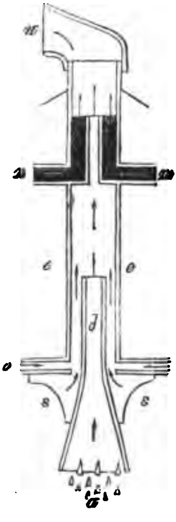
FIG. LXXXVIII.



vitiated atmosphere of the room rises into the lower air box, and passes through the hot pipes into the box, *e*, and thence through the pipe or channel, *m*, into the atmosphere.

As a *ventilating* fireplace, the Chabannes' calorifere is unexceptionable; the *small* pipes being enveloped with the burning fuel and flame, are made red hot, and produce a high degree of rarefaction in the intercluded air, which gives it a very great velocity; and where it is inconvenient to enclose the ashpit, or to make the air rise through the fuel, the calorifere will be found a convenient and effective ventilator. Its merits stop here. As an apparatus for heating air to be respired in a room, it is one of the worst of its class. With a very moderate fire the pipes must be so hot as to burn not only the light substances floating in the air, but decompose the air itself. Its construction also prevents in a degree the perfect combustion of the fuel, and it has much the appearance of an enclosed stove, which is considered a defect in a grate for an open fire, as being unfavourable for the emission of the radiant heat.

FIG. LXXXIX.



The marquis heated and ventilated some large buildings. In a theatre, he made the heat from a large chandelier, suspended from the roof, perform the office of ventilator. In Fig. LXXXIX. *a* is the chandelier; *d*, a wrought iron pipe, carrying off its heat and smoke; *e*, a wooden case into which the air flows at *o* and *s* from the ceiling; *n*, *m*, pipes conducting the vitiated air from other parts of the house. He placed a large calorifere in one of the galleries, which drew off the vitiated air from several tiers of boxes. In this, of which Fig. XC. is a plan, and Fig. XCI. a section, the flue acts on 12 pipes, *a*, *a*, each 7 inches in diameter, 10 feet in length, and united in a single pipe, *o*, 2 feet in diameter; *k*, the furnace, which is supplied with coal from the hopper; *n*, *i*, the ash-pit; *d*, an enclosed chamber into which the ventilating pipes, *c*, *c*, *c*, are carried from those parts of the building to be ventilated, which then rises through the pipes, *a*, *a*, in the furnace, into *o*, and thence escapes by the cowl. Fig. XCII. is a section of the upper part of the pipes, *a*, showing the manner in which the hot vapour from the furnace, after enveloping the air tubes, is conducted at *p*, *p*, into the smoke flue. He placed another calorifere over the stage, and the gas chandelier ventilated the centre.

FIG. XC.

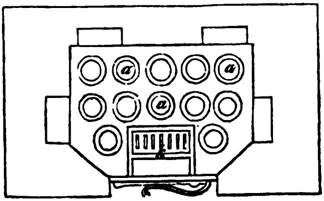


FIG. XCI.

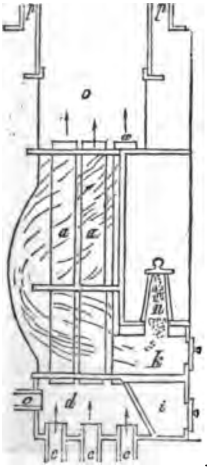
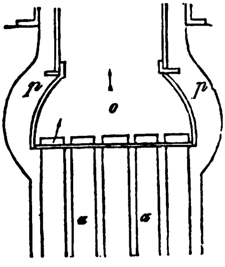


FIG. XCII.



The vitiated air from all parts of the house was emitted above the roof, through three trunks, each terminated by a cowl; a trunk being placed over each "power," as the marquis properly called his furnaces, or caloriferes.

In heating the theatre, the general arrangement of his apparatus was judicious and ingenious. To replace the air carried off by these energetic ventilators, a calorifere was placed at *every* entrance and staircase communicating with the external air, so that the atmospheric current rushing from without to restore the equilibrium in the interior, being warmed, it warmed the spaces into which it entered. A number of cylinders were placed under the stage, into which steam was admitted and heated the air flowing through 30 pipes 2 inches in diameter that were enclosed in each; caloriferes were also placed at other points, and it was attempted in every part of the immense building to avoid the dangerous draughts of air that are always found in such edifices. The marquis made Covent Garden Theatre the most comfortable place of public amusement in the metropolis, without his usual extravagance in the heating medium, and if he did not succeed in pleasing all the players and playgoers, that is only saying he could not perform impossibilities; and the gaping idle herd knew not, or could not appreciate, the numerous obstacles that he had fairly overcome in producing so much comfort as he did. The air in the house was described as "stifling," and in the cold weather it did feel dry and parching—but the same effect *must* be produced when air is heated from 32° to 65° by any apparatus whatever; and, therefore, this should have formed no depreciating objection to that air in particular which was attempered with heat by the marquis.* The manner in which he applied his calorifere being the same, however, as that followed by Mr. Sutton and others, his ambition to be thought the author of "forced ventilation," can therefore only be gratified by doing a "crying injustice" to those who practised the same method a century before his apparatus was invented.

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* In ventilating the House of Commons the marquis swept away the "classical apparatus" of Wren and Desaguliers, to make room for a capacious air trunk over the ceiling, into which he led the tubes that conducted the vitiated air from different parts of the house. Inside the air trunk he placed a number of cylinders filled with steam to produce a rarefaction; and the air which entered the trunk through the ventilating tubes he carried into the atmosphere by a chimney with a cowl 4 feet in diameter. There was no lack of ventilating "power" in this apparatus in certain circumstances. It gave, however, as little satisfaction to the speechmakers in the one

To free rooms from distressing heat and cold, Mr. Vallance made his windows and room air-tight, and left one aperture only in the ceiling and one for the door. The doorway, 6 feet wide and 6 feet high, was fitted with a cylinder of wood closed at both ends and placed upright so as to resemble a cask built into the wall. In the side of this cylinder there was an opening 4 feet wide, and on the opposite side there was another of the same size, of the height of the cylinder, forming a way 4 feet wide into the room. In the centre of this cylinder he fixed a perpendicular revolving shaft with four arms or leaves, at right angles to each other, like a winnowing machine, which fitted the inside of the cylinder as closely as practicable to permit its revolving motion, and yet prevent the air escaping at the edges of the fans; each person that entered the room placed himself between two leaves like a turnstile, and by this means as much cold air only was admitted into the building as surrounded himself. To the aperture in the ceiling a pipe was fixed and carried through the roof, where it was inserted a few inches into a cistern of water.

Into this air-tight room Mr. Vallance injected air by means of a pump worked by machinery. When the atmosphere was warm, the injected air was cooled

House as it had done to the speechmakers in the other. The air was introduced at too high a temperature, from an excess, perhaps, of heating surface, without effectual means for its prompt regulation; and from inattention to the effect of lateral openings, the atmosphere had at no time been so variable and so ungenial as it was while this apparatus was in operation. Everything had been overdone, and after a trial, that was a long one considering its imperfections, the caloriferes were abandoned.

by passing through pipes filled with cold water, and they were immersed in hot water when the air was to be heated. As the fresh air was pumped in, as much vitiated air was forced out at the pipe in the ceiling, and it rose through the water in the cistern into the atmosphere, which thus regulated the pressure of the air in the apartment.* The idea is most ingenious, and by this excellent practical water valve, which enables us to preserve and regulate, in a simple and most effective way, a condensed as well as a heated climate, Mr. Vallance may be said to have perfected Dr. Henshaw's first thought, without, most likely, ever having heard of it.

When a room is filled with condensed air, its expansive principle will be exerted, and as Mr. Vallance observes, "every crack and crevice about the place will become a channel to let air *out*, instead of into it, and thus drafts are effectually prevented, owing to every cranny becoming a channel of egress instead of ingress." But the air injected into a room will not produce a perceptible current where the apertures are properly proportioned.†

The contrivance employed by Desaguliers, to ventilate the House of Commons, is now used for drawing out the heat, moisture, and dust from the rooms in factories, and to keep the air light, fresh, and agreeable. A variety of fanner, considered to be an improvement on the ancient model, is shown in Fig. XCIII.: *c c* are the fans, and *o o*, the case in which they revolve; *x*, the central aperture for the admission of air; and *f*, the channel through which the air is expelled. The fresh air enters at *x*, and by the revolution of the fans is condensed at their extremities, and makes its escape from the pressure through the exit pipe, *f*, while the external air is continually pressed in at the central opening to restore the equilibrium.

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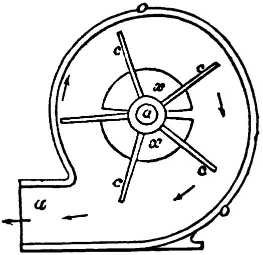
* Observations on Ventilation, p. 75.
Mr. Vallance proposed to condense air and liberate part of its latent heat, and then to mix a certain quantity of this condensed air with the warm air at the ordinary pressure. The expansion of the condensed portion would cool the mixture. Dr. Darwin found air liberated from a pressure of an atmosphere, depressed the thermometer 4°.—Considerations, p. 7. He anticipates the time when houses, in the confined parts of London, will be ventilated by companies, like the water companies.

† In the air vault of a blast furnace, into which 9300 cubic feet of air were injected in a minute, under a pressure of 5 inches of mercury, Mr. Roebuck did not observe any appearance of wind to disturb the flame of a candle; neither was it blown out when he placed it in the eduction pipe of 16 inches diameter, through which this quantity of air was passing into the furnace.—Repertory, vol. xiii. p. 19.

FIG. XCIII.



The fans constructed by some engineers are like that which have been described at page 41, with their mantles or cases made concentric with the central shaft; but though they do good work when turned with sufficient rapidity, they are not adapted to produce pressure by condensation. The air in the fan in the above cut, undergoes compression during its whole progress through the spiral space with the revolving fans, and is equal in density to that compressed at their extremities by the centrifugal force; and the fan discharges more air than if it had the concentric casing.*

When the temporary building for the House of Commons was supplied with heat and air, its atmosphere was quite as defective as any that had pervaded the ancient building. The modifications introduced by Dr. Reid, under whose direction it was greatly improved, will be understood by inspection of Fig. XCIV. The external air is admitted through a coarse gauze screen into a porch communicating by doors with a room under the house. At one of these doors is placed the heating apparatus, *b*, which consists of a collection of hollow cases, formed of parallel cast iron plates or pipes, containing hot water, and placed at a small distance from each other; the air from the porch, heated in passing through the intervals between them, flows into the warm air chamber, *d*, from which it is conveyed, through about twenty apertures, *e e*, made in its ceiling, into a space formed under the floor of the house: from this space about

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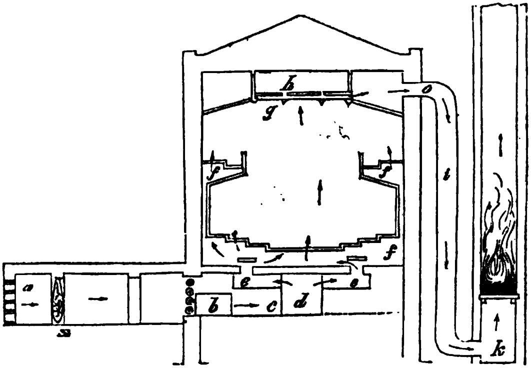
* Ure. Phil. of Manufactures, p. 384.

FIG. XCIV.



36,000 cubic feet of air every minute rise by several hundred thousand holes, about a sixth of an inch in diameter, made in the floor and under the seats in the pit and galleries. The ascent of this pure warm air into the house expels the effete air through openings formed in the ceiling, by some of the panels with which it is ornamented, being raised about an inch above their styles. By these apertures the air passes into the space, *h*, under the roof, and thence it is conducted by the descending tunnel, *i*, into the ash pit, *k*, and rising through the fire in the furnace, *m*, is emitted into the atmosphere at the summit of a chimney-stalk about 100 feet in height.*

The room under the floor, that forms the warm air chamber, is partitioned so that, by opening certain doors, cold air may be admitted either to reduce the temperature of the warm air flowing into it from the heating apparatus, or to fill it with pure unwarmed air when that only is required.

The air is also supplied with moisture, previous to its admission into the house. Dr. Reid, in 1838, said, that 5000 feet of moist surface were used to produce the required effect;† and it has been subsequently stated that it now receives the necessary moisture by means of pipes filled with water, which are placed on the floor of the porch, and perforated with a number of small holes. The water issues in jets from the minute orifices and produces a spray, which is considered to freshen and purify the air that is made to pass through it. On one occasion 70 gallons of water in the form of moisture were thrown into the house in a few hours.‡

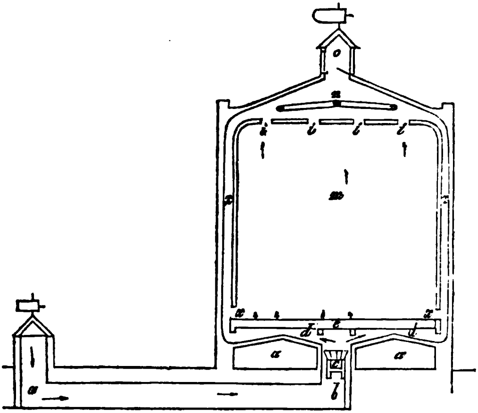
The perfect regulation of the heating and ventilating process does much credit to Dr. Reid's contrivance. The want of this control was the great practical defect of every former apparatus. By making the impure air flow through the fire, as Mr. Evelyn and Mr. Sutton did, the doctor produces a much higher degree of rarefaction than could be formed by any other method, besides making the furnace itself act as a valve to prevent the counter current, that destroyed the effect of the previous

* Richardson: Warming and Ventilation of Buildings, p. 100.
† Reports of British Association, vol. vii. p. 132.
‡ Chambers. Information for the People, p. 664.

apparatus on the same principle. The descending motion given to the respired air, in bringing it from the ceiling of the house into the cavity under the furnace, seems, however, an unessential part, that was, perhaps, introduced to have the furnace as accessible as local circumstances would permit; its only effect being to diminish the velocity of the ventilating column, which in every other part has been most skilfully and successfully preserved. Neither is it obvious that a very elevated chimney-stalk is a necessary appendage to a ventilating furnace, unless as high a temperature can be preserved throughout its capacity as the gaseous product of the combustion has when escaping from the fuel; a condition that is not attainable in practice. The temperature at which the gases rise from the surface of the fuel is not increased by the height of the chimney above the grate, and as this influences the current into the ash-pit, and consequently the velocity with which the air is drawn from the room, a chimney that rises a few feet would be as effective as one carried to a great height above the fireplace.

Mr. Sylvester, whose experience gave his opinion much weight, was also consulted as to the means he would advise for ventilating the same building. A sketch of his plan is shown in Fig. XCV. The general principle he would recommend was, he says, to introduce the fresh air slowly, and in any quantity desired, without reference to temperature, and then to provide means to heat it so as to make it agreeable to be breathed at all times. The underground channel, *b*, about 9 feet square in area, would form a communication with the atmosphere and the basement floor of the building; its outer extremity, *a*, would have a cowl made so as always to turn its opening towards the wind. The fresh air flowing along this tunnel for about 100 yards, would receive in winter about 15° of heat, and in summer it would be the same number of degrees colder. It then would pass into the apparatus, constructed on the model of the Belper stove, and being heated to within 5° of the temperature required in the room, would spread in the space, *d d*, under the floor, and rise through a great number of small orifices disposed throughout its area, *e*, into the body of the house, *m*. The respired air would then be carried off through a series of apertures, *i*, in the ceiling, which would be constructed to be shut or opened at pleasure, by an apparatus communicating through *x* to the basement. When the vitiated air had risen through these valves, it would then flow into the cavity, *n*, of the roof, from which it would be emitted into the atmosphere by the turn-cap, *o*, constructed so as always to have its mouth turned *from* the wind. Mr. Sylvester on this occasion deviated from his common practice, and advised that a series of pipes, *n*, filled with steam or hot water, should be introduced into the cavity of the roof to raise the air in that part to a higher tempera-

FIG. XCV.



ture than that in the house, in order to insure the required velocity in the ventilating current.

If at any time it was necessary to supply the fresh air at a higher temperature than that in the body of the house, the valves in the ceiling would be closed, and the vitiated air would escape at the openings, *x*, *x*, near the floor, and through channels, *x x*, in the walls into the cavity in the roof.

Mr. Sylvester stated that the rate at which air can be economically set in motion through the channel for supplying the fresh, and discharging the vitiated air, is about 4 feet in a second; but the rate at which he considered it would be desirable to make it flow into the house would be about 30 feet in a minute; and at this speed the current would scarcely move the most sensitive flame. The floor of the house and passages he calculated to have an area of 4000 superficial feet, and its content at 200,000 cubic feet. The area of the apertures distributed throughout the floor would be about 665 feet, and through these 20,000 cubic feet of air would rise every minute, so that the whole air in the apartment would be discharged and renewed six times in an hour.*

As an effective and convenient method of renovating an artificial climate, thermo-ventilation leaves little to be desired. The objection has, however, been made to it, that it is more expensive than fan ventilation, and that the air of the room rarefied by the powerful draught of a high chimney-stalk, which operates by pumping out, exhausting and attenuating the air, may prove detrimental to vivacity and health. Saussure's observations demonstrate how difficult and painful it is to make muscular or mental exertions in highly rarefied air. Even the slight rarefaction of the atmosphere corresponding to a low state of the barometer at the level of the sea, is sufficient to occasion languor, lassitude, and uneasiness to persons of delicate nerves. Among the numerous causes, Dr. Ure observes, who urges the objection, that are assigned for the infirm health of persons who confine themselves much to warm apartments, and seldom venture into the open air, one of the most operative has been altogether overlooked—the rarefaction by diminished pressure and heat of the atmosphere which they breathe. Many of the ailments of the opulent may be traced to their breathing air unduly rarefied by chimney draughts. If a differential barometer have its horizontal tube thrust into the key hole of a snug winter parlour, it will rise from half an inch to an inch, according to the tightness of the room and force of the fire, and by opening the street door a farther rise will take place. And, referring to the climate produced in the House of Commons by the means described in a previous page, he observes, that among gentlemen plunged in air so attenuated, condensation of thought and terseness of expression can hardly be the order of the day.* Saussure's authority is unquestionable; but it should be remembered, that while he was inhaling the attenuated air, he was benumbed with its extreme cold. It must also be admitted that numerous communities exist at elevations of 6000 feet above the level of the sea, and that the rarefied air in which they live in no way impairs either their mental or bodily energy, but, on the contrary, is considered to increase both. Nay, further, the air thus attenuated from position, is further attenuated by its being artificially heated by German stoves and braziers to a temperature of 65° or 70° F., without injurious consequences to the health either of mind or body of those who breathe it.

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* Report on the Ventilation of the Houses of Parliament, p. 47.

Injecting air into rooms by means of fans or pumps can increase the density of their atmosphere only when the floors, walls, and ceilings of the apartments, and windows and doors, are made air tight, and the vitiated air escapes by some regulating mechanism, like the ingenious valve of Mr. Vallance,—conditions which, it is obvious, would not be practicable in the case of rooms having a constant ingress and egress of persons like the House of Commons. Fan ventilation, as now applied in the factories, does not condense the air in the room; for neither windows, nor doors, nor floors, are air-tight, and the orifice emitting the vitiated air is open to the atmosphere. Whether, therefore, the atmosphere of a room in these circumstances be renewed by thermo-ventilation or by fan ventilation, the barometer would indicate the same aërial density in each.

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* Architectural Magazine, vol. iv. p. 180.

With regard to the expense of the two methods, fan ventilation has been thought to be the cheaper. The apparatus by which the estimate was made, was, however, a very perfect one, and the thermo-ventilator compared with it should, in fairness, be considered (as far as its furnace is concerned) as an experiment only, and capable of great improvement.* No direct experiments of comparison have been made on the subject: but, if each apparatus be constructed with equal skill, it is probable that small difference of expense will be found between them.

In the Bank of Ireland, and also in the Bank of England, Mr. Oldham adopted the hollow heating plates filled with steam, of Mr. Deacon's eolians, and forced fresh air through them by a pump attached to a steam engine.† He made no other provision for ventilation than apertures in the ceiling and side of the room, for the escape of as much vitiated air as of fresh air thrown in by the pump. Mr. Eaton, also, in some buildings that he has ventilated, made the external air pass between hollow cast iron plates, like those used at the Bank of Ireland, but they were heated by the steam of condensation from the steam engine that moved a ventilating fan, and performed other household services. He ventilated by apertures in the common manner. Where the introduction of a steam engine is not objectionable, both methods may be considered effective and economical.

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* Arch. Mag. vol. iv. p. 177.

† Williams. Civil Engineer's Journal, vol. ii. p. 96.

Among other schemes in vogue that of Mr. Perkins is at present one of the most prominent. He occasionally ventilates by a descending current, as Mr. Strutt did, but in general he follows the common method. Mr. Price in his practice attempts no novelty. The apparatus of both has been introduced with success into several extensive buildings.

The difficulty of ventilating a large public room had been exhibited in the failures of several apparatus erected in the Custom House. There the climate, in some of the apartments, was so defective as to produce general symptoms of ill health among the officers whose official seats were placed in it. These functionaries were described to have had "a sense of tension or fulness in the head, with occasional flushings of the countenance, throbbing of the temples, and vertigo, followed not unfrequently with a confusion of ideas that must be very disagreeable to officers occupied with important, and sometimes intricate, calculations. A few were affected with unpleasant perspiration on their sides. The whole of them complained of a remarkable coldness and languor at their extremities, more especially the legs and feet, which became habitual. The pulse, in many cases, was more feeble, frequent, and sharp and irritable, than it ought to have been. The sensations in the head occasionally rose to such a height, notwithstanding the most temperate regimen of life, as to require cupping, and at other times depletory remedies; and costiveness, though not a uniform, was yet a prevailing, symptom."

This formidable catalogue of "affections" was thought by the scientific smoke doctor who drew it up, wholly attributable to the imperfection of the heating apparatus, and he judiciously advised the hot air stoves, which he considered generated the malaria, to be removed, and in their stead pipes heated by steam to be laid along the floors; and fresh air supplied to the room by an eccentric fan moved by a steam engine.* This suggestion of a practical and approved arrangement was not, however, acted upon. Dr. Arnott, who was afterwards consulted and employed, produced a comfortable and wholesome climate in the long room, that contains half a million cubic feet of space, by means of three warm air stoves of his contrivance placed on the floor; and he ventilated this great space by six small casements made in the borrowed lights in the cove of the ceiling, through which the air rushed with a velocity proportioned to the rarefaction and quantity of air admitted under each of the stoves.† This most simple arrangement has been found not only economical but even salubrious; for all the annoying symptoms of disease, under the use of the old apparatus, have, it is said, disappeared. The ventilation therefore is more perfect; although, to a casual observer, the climate *feels* as defective as before.

In small rooms heated by stoves still more serious effects are produced by want of ventilation. In Russia, says Dr. Thomas, the common people are frequently deprived of sensation by vapours arising from the following cause. Persons of rank in that country have double windows to their houses in winter, but those of the poorer classes are single only.

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* Arch. Mag. vol. iv. p. 162.

† Fowler. Trans. of Institute of Architects, vol. i. p. 169.

During frosty weather an encrustation is formed on the inside of those windows, from a condensation of the breath, perspiration, &c., of a number of persons living in the same room. This mephitic crust is mixed with the noxious fume of candles, and of the stove with which the room is heated. When a thaw succeeds, and this plate of ice is converted into water, a deleterious principle is disengaged which produces effects similar to that arising from the fumes of charcoal. Persons affected by this effluvium are immediately carried out of doors and placed on the snow, with no other covering than a shirt and drawers; their temples and region of the stomach are then well rubbed with snow, and cold water poured down their throats, and the friction is continued until the livid hue of the skin disappears and it acquires its natural colour.* The Chinese, whose rooms are as small, as hot, and as crowded as those of the Russians, escape some of their evils by having two apertures, open night and day, at the top of each window, to renew the air which they think is too much rarefied by the heat.†

The method adopted by Mr. Sylvester, of drawing fresh air from an underground tunnel, as a means to warm it in winter and cool it in summer, was similar to that described by Palladio as practised by the Vicentine gentlemen, Trenti, in their villa at Costoza. Some large caves, that had been quarries, in the neighbourhood of their palazza, were noted for the coolness of their air; on one of these neither care nor cost was spared, and was worthy, says the prince of architects, of our admiration.‡ From this spacious cave or grotto, called by its possessor Æolia, subterranean tunnels or ventiducts were carried through the rock and communicated with every room in the villa. "When they would have a cool air," says Ray, who visited it in 1663, "in any of the rooms, they shut up a gate in the cave and open a door at the end of the channel which lets in the fresco; every room having a hole in the wall or pavement to admit it."*

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* The Practice of Physic, p. 907.
† Phil. Trans. vol. lxi. p. 69.
‡ I Quattro Libri, l. i.

Punkahs are a sort of horizontal fans suspended from the ceilings of large rooms in India where company assembles. They are made to vibrate to and fro over the heads of the company, and seem intended rather to keep the air that is in the room in motion than to introduce a fresh supply by ventilation. In these climates this motion is refreshing, although, to Europeans who have not been accustomed to it, it is not at first agreeable. From time immemorial these implements have been made to vibrate by hand; but about five and twenty years ago a steam engine was sent from England to move the punkahs in the palace of the Nabob of Oude.

Tatties, also, are in general use in India as ventilators. These are a kind of mat, affixed to the door or window frames. Some of these tatties are made of *kus*, which is a light brown root dug out of the earth, about a foot and a half long and a foot broad. This is split and put into a frame made of bamboos, so as to fit the doors. The *jooaga* is another root used for the same purpose. It is of a lively coloured green, and when watered diffuses an agreeable scent through the bungalow, and is a pleasing relief to the eye in Indian houses, in which nothing but white plastered walls are to be seen; but a tattie made of jooaga requires to be changed every three days, whereas the kus will remain good during the whole hot season, which generally lasts for months. The tatties are kept constantly sprinkled with water, and although the winds are scorching hot which drive against them, yet a most refreshing breeze is experienced in the bungalow. The degree of cold produced by their means is supposed to be in proportion to the heat of the wind which passes through them, as on that depends the rapidity of evaporation. On the 26th May, at 2 o'clock in the afternoon, the thermometer in the sun, with a hot westerly wind, rose to 118°; when it was placed in the shade, but exposed to the wind, it fell to 110°; while in the house, kept cool by tatties, it stood at 87°. In another experiment, on June 7, the thermometer, when exposed to the sun, rose to 113°; in the shade and hot wind it fell to 104°; in the house, cooled by tatties, it descended to 83°.* In the same place water taken from a well 60 feet deep had a temperature of 74°, and when it was poured into a porous earthen vessel, and exposed in the shade for three hours to a hot westerly wind, its heat was 68°. From which it is evident, says Mr. Gray, that the labour of raising the water and sprinkling it on the tattie might have been saved. Had the air been admitted through an underground tunnel, or from the well, to the apartment, it would have been several degrees colder than if refrigerated by tatties.

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* Itinerary, p. 218.

In reviewing the various schemes that have from time to time been offered to the public, it is worthy observation, that ventilation is a process so simple in itself, yet withal so delicate, as to be easily impeded or destroyed, even by seemingly skilful arrangements to promote it; and more attempts have failed by aiming to produce the effect wholly by comparatively complex artificial means, than by relying on a simple modification of the natural process, which would have served the purpose as effectually; and it is also clear, that all the methods noticed are practically sufficient for the perfect renewal of an artificial climate; but from the frequent failure of apparatus on every construction, it is also evident that any one "system" is not sufficient to meet the exigence of numerous cases that occur in practice; and perhaps not even every point in cases where it is generally proper. Hence the disappointment that is so often experienced when the statements are implicitly received of an inventor or improver, who displays his apparatus as being one that is calculated to be beneficially introduced into buildings, varying widely in their structural arrangement, and used for the most opposite purposes.

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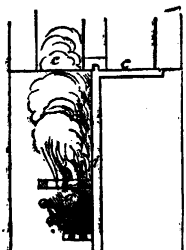
* Williams. Phil. Trans. p. 131. 1793.

ESSAY XI.

DURING a voyage from France to America, in 1785, Dr. Franklin amused himself by drawing up an account of some contrivances that he had, at various times, seen practised to heat apartments. In this he describes a fireplace that he saw in Paris, which was ingeniously constructed to heat conveniently a study and a bed-room with the same fire.

The funnels, *c c*, over the fireplace, Fig. XCVI., were circular; the fireplace, *a*, was of cast iron, having an upright back, *i*, of the same material, to which was attached a plate, *c*. The back plate, *i*, turned on two pivots, and the plate, *c*, always closed that flue in the room in which there was no fire, and the flue over the fire was always open. In the figure, the fireplace, *a*, is shown as adapted to burn coals, but where wood is the fuel it may be consumed on the hearth plate, *r*, which is attached to the back plate.

FIG. XCVI.



When a fire was made in the grate, *a*, the iron back, *i*, was quickly heated; and the air in contact with it, with its surface towards the adjoining room, being prevented by the valve plate, *c*, from escaping up the chimney, *s*, it spread throughout the room and warmed it. By this means a servant could, at any hour in the morning, make a fire in the study, which would also warm the bed-room without disturbing the master by going into his chamber; and the master, when he rose, could, with a touch of his foot, turn the fireplace on its pivots, and bring the fire into his bed room and keep it there as long as he wished, and at going out turn it back again into his study. When retiring to rest in the evening he would find his bedchamber comfortably warmed by the hot back plate, and if he wished to have a sight also of the fire he could turn it towards him.

If it were desired to have hot air introduced into the room in which there was no fire, the back plate might be made hollow, and an opening made at the bottom for the admission of the cold air into the cavity, and another at the top of the air box for its emission into the room.

Few contrivances in heating could be turned to better account than this. In small houses, where fires are seldom made in bed-rooms, this elegant mechanism would be a treasure of comfort and enjoyment.

The revolving grate, a front view of which is shown in Fig. XCVIII and side view in Fig. XCVIII†., was invented by His Excellency the President of the State of Pennsylvania. The fire cage is circular, and about a foot in diameter, and may be from 6 to 8 inches wide from front to back. The back is of plate iron, and the front is filled with bars, as shown in the figure. The three middle bars are fixed, but the upper and under ones, *a*, *x*, are moveable, and may be drawn out at pleasure with pincers or tongs. The sides of the grate are also made with plate iron, but an open space is left at top and bottom; this space is filled with bars, which at bottom form the grating on which the fuel is laid, and at the top they allow the smoke to escape through them. The round fuel cage turns on its axes, *i i*, which are supported by a crotchet fixed to the stem, *c*, that revolves upon the upright pivot, *e*, that is fixed to the hearth plate. Small nobs, *o*, are fixed in the middle of the top and bottom grates.

FIG. XCVII.

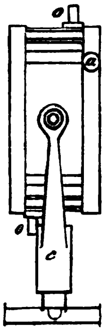
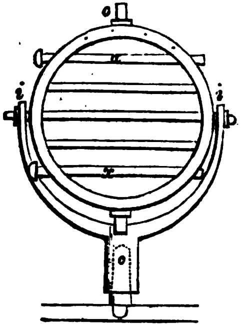


FIG. XCVIII.



At first making a fire in this grate the upper bar, *a*, is taken out, and the wood and coals introduced and placed as in common grates; and the bar is replaced when the grate is charged. When the fire requires to be replenished with fuel the upper bar is again taken out, and fresh coal placed, as in common fires, on the top of the burning fuel; the moveable bar is then replaced as before. While the grate is in this position the fuel will throw up a body of thick smoke; but every one must have observed that pieces of fresh coal stuck in *below* the red coals have their smoke converted into flame, and here is the use of the swivel grate. By a push with the tongs or poker it is turned on its axes, *i i*, until the front bars of the grate face the back of the hearth recess, and what is the back of the grate faces the room. The fresh coals will now be *under* the burning coals. The whole apparatus is then turned round on the upright pivot, *i*, so as to make the bars again face the apartment, and the smoke from the fresh coals rises through the incandescent portion. The fuel being thus more perfectly consumed, a greater quantity of heat is emitted into the apartment. It has another advantage, with a touch it may be turned from any one of the company that desires to have less heat, or presented full to one just come out of the cold. When the front bars are placed in a horizontal position, a tea-kettle, or any cooking utensil, may be most conveniently set on it.* In this grate, a full sight of the burning fuel, always a pleasing object, is enjoyed; the round figure of the fire, also, when thoroughly kindled, is agreeable, and represents, says the doctor, the great giver of warmth to our system.

Of all the labourers to increase fireside comfort, Count Rumford deservedly acquired the highest honour. Like other benefactors, his schemes experienced the opposition and sneer of some of the wit-worms of the time; but these were infinitely overbalanced by the approbation of the benevolent, and above all by the gratitude of that class whose comfort he advocated, and which he may be said to have established. To induce society to engage in any enterprise, it is necessary, he remarks, to show, not only that it will produce real advantage, but that it can be attained without much difficulty; and as examples of success are often more efficacious in stimulating mankind to action than the most conclusive reasonings and earnest admonitions, "why," says the count, "should I not mention, as an inducement to others to exert themselves in the same cause, even the affectionate regard and respect which I received from the poor people for whose happiness I interested myself, and the testimonies of public esteem with which I was honoured. Will it be reckoned vanity if I mention the concern that the poor of Munich expressed in so affecting a manner when I was dangerously ill,—that they went publicly in a body to the cathedral church, where they had divine service performed and put up public prayers for my recovery,—that four years afterwards, on hearing that I was again dangerously ill at Naples, of their own accord they set apart an hour each evening, after they had finished their work in the military workhouse, to pray for me? Will it be thought improper to mention the affecting reception I met from them at my first visit to the military workhouse, upon my return to Munich after an absence of fifteen months, which drew tears from all who were present? Let the reader ask himself, if any earthly reward can possibly be supposed greater,—any enjoyments more complete than those I received. Let him figure to himself my situation, sick in bed, worn out by intense application, and dying, as everybody thought, a martyr in the cause to which I had devoted myself,—and then let him imagine my feelings upon hearing the confused noise of the prayers of a multitude of people who were passing by in the streets, upon being told that it was from the poor of Munich, (eighteen hundred in number,) who were going in procession to the church to put up public prayers for me—for a private person, a stranger, a Protestant!"

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* Phil. Papers, p. 80.

But few better deserved this spontaneous homage than the apostle of fireside comfort, whose improvements on chimneys have that philosophical simplicity which makes them easy in execution and universal in application.

These improvements will be better understood by referring to the manner in which chimneys were usually constructed, and the grates placed in them, when the count introduced his system. Fig. XCIX.

is a section of a hearth recess, showing the manner in which the grate was placed in it when the chimney-breast was of an uniform thickness; and Fig. C.

FIG. XCIX.

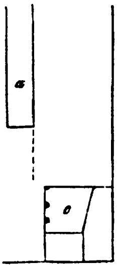
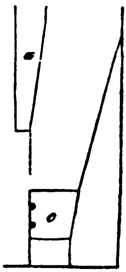


FIG. C.



shows how the grate or stove was set when the breast was built half a brick in thickness, to allow the grate to be brought further forward in the hearth recess. From these figures it is apparent that the flue was a passage for all the warm air in the room to flow into the atmosphere, instead of being a passage for the smoke only that rose from the fuel.

The necessary consequence of air being rarefied by heat is, says the count, that it would be as great a miracle if smoke did not rise in the chimney, as that water should refuse to run in a syphon or descend in a river; and as it always rises perpendicularly, the proper place for the commencement of the flue is perpendicularly over the fire, and the back of the fireplace should be vertical. The smoke being hotter near the fuel than at a distance above it, the nearer the underside, or soffite, of the mantel is to the fire the higher will be the temperature of the vapour rising into the flue; consequently, the greater will be its velocity, or the stronger will be the *draught* of the chimney.

But when the draught is very powerful, from the mantel being placed low, the fuel swales too rapidly; and when the mantel is too high, the column of smoke is so much cooled, that a slight obstruction, either from the wind at the chimney top, or from an imperfect construction of the smoke canal, or from persons opening doors, or passing quickly in front of the fire place, brings the smoke into the chamber.

From the ever varying temperature of the incandescent mass, it is obvious that to produce a uniform velocity in the column of smoke, the height of the mantel soffite above the fuel should vary also: but although of great practical importance, no means are in use to produce this adjustment, and all that has been attempted is by a rough approximation to adapt its height to one or two of the many conditions of the problem.

It is probable that the common varieties of pit-coal, in small uniformly sized pieces burned in an open brazier, supplied with air from the bottom, and having a depth of 3 inches, are consumed as perfectly, and give out as much heat, as in any other form of apparatus. But to save the trouble of frequently supplying fuel, the depth of the coal is generally made from 5 inches to 9 inches; and a fire 7 inches thick may be a fair average case of what is popularly considered to be the most economical arrangement of the fuel.

A fire of this depth will consume a certain quantity of coals in a certain time, and of course will produce a certain quantity of heat and smoke; and the count's object was to produce a perfect combustion of the fuel, in the *longest* time, and throw as much of this heat into the room as possible; unlike modern practitioners, he avoided every thing that had a tendency to hasten the consumption of the fuel.

The length of a smoke flue has no effect in accelerating the velocity of the air, flowing towards a fire placed in a chimney, except from what has been called the lateral communication of motion that would take place from the ascending current, when the mantel or the throat is placed very low; and the count was careful to avoid the undue waste of the fuel from this cause, by placing the fire as far beneath the mantel as was consistent with the preservation of a due velocity of the vapour in the flue; for the combustion being equally perfect, the lower the temperature of the fuliginous vapour rising from the fuel, at its entering the throat, the more heat will be thrown into the room. All the heat that the smoke has at issuing from the chimney is so much heat thrown away—is so much coal consumed to no purpose. In common cases, three-fourths of all the fuel burned escapes, and is wasted at the chimney top.

The distance therefore at which the soffite of the mantel or mantel bar should be placed above the fire, without the combustion of the fuel being affected by the motion of the ascending column of smoke, and that motion be the slowest possible, he found in common cases to be about 14 inches, when the flue was wide and short; and it did not exceed 20 inches, where it was carried to a considerable height. When the room was spacious, and the grate contained a large quantity of fuel, he sometimes raised the mantel 2 feet above the fuel; but this bold practice was generally forced upon him by some circumstance connected with the architectural appearance of the apartment, and in these cases he always operated under a sort of protest. He was never satisfied with the rash experiment, and it seldom in the end pleased the patron. If the chimney was an inveterately smoky one, he was obliged, like other doctors, to resort to the extreme remedy of *lowering* the mantel sufficiently to cure it, and feel no compunction at the waste of fuel, "which I think," he says, "is not to be compared to the greatest of all plagues, a smoky chimney."

Cardinal Polignac attempted to reflect the radiant heat into the room from parabolic covings; but the great depth of the hearth recess marred the ingenious intention, and Clavering's oblique jambs were ineffective from the same cause.* The count produced the desired effect in a different manner. He brought the fire more forward into the room, or rather nearer the opening of the fireplace, diminished the throat of the flue, and made the covings diverge.

To the question of how far the fire should be brought forward, the answer, says the count, is short and easy to be understood. Bring it as far forward as possible, without diminishing too much the passage that must be left for the smoke; and as this passage should be left perpendicularly over the fuel, its size will determine the projection of the fire into the room.

He took great pains to determine, experimentally, the proper size that should be given to this passage. The average width from front to back of a parlour fire being taken at 8 inches, he found, that when the back of the fireplace was of the right length, and the flue of the usual size, *four inches* was the best width for the smoke passage, at the part where it joined the flue, and he called this part the *throat*. Where the grate or box containing the fuel is small, 3 inches might do; "but, as it always is of importance to prevent those accidental puffs of smoke which are sometimes thrown into rooms, through the carelessness of servants putting on suddenly too many coals at once upon the fire, and as these accidents sometimes happened when the smoke passage was made very narrow, I found," says the count, "all advantages and disadvantages being compared and balanced, that 4 inches is the best width;"* and if it appears extraordinary, that fireplaces of different sizes should have their throats of the same width, it is to be considered, that a long fireplace will have a long throat, and the size of the passage is the length multiplied by its breadth. The throat of a chimney should always be made to commence at the soffite of the mantel, or underside of the breast wall.

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* Essay on the Construction of Chimneys, p. 93.

The size of the back of the fireplace is next to be decided. The hearth recess is generally built as wide at the back as in front, with the jambs parallel; but when the fire is brought forward, *one third* of the width of the hearth recess is the proper width of the back. "The form is perfect when the width of the back is equal to the depth of the fireplace, and the opening of the fireplace three times the width of the back." The depth of the fireplace being the distance between the line, *c*, *t*, and back, *x*.

FIG. CI.

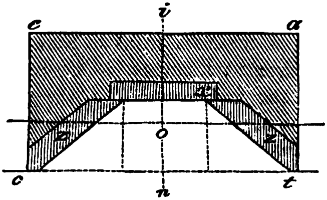

Fig. CI. is a plan of the hearth recess, and Fig. CII. a vertical section taken from front to back. In laying out the work, the count directs a line to be drawn with chalk upon the hearth, between and even with the jambs, *e*, *f*, of the hearth recess, *e*, *c*, *d*, *f*; in the centre of this line, another line must be drawn at right angles to it, from *o* to *i*. The bricklayer must now stand upright in the chimney with his face to the room, and hold a plumb line to the middle of the upper part of the chimney breast, *m*. Great care must, however, be taken to place the line *high up* in the chimney, and in *all* cases, to the part where the flue begins to rise perpendicularly; otherwise, if placed against the slope that is sometimes made in the breast (as in Fig. CIV.), when the back is raised to its proper height, the smoke passage will be found too narrow. This precaution being observed, and the plumb being made to fall on some part of the line, *n i*, that point, *o*, is to be marked by an assistant; 4 inches are next to be set off from the point, *o*, towards the back, *i*, and a line drawn through it parallel to the line, *c t*. This line forms the back, *x*, of the new fireplace; its length is *one-third* of the width of the hearth recess, and a line drawn from its extremities to the outer edge of the jambs, *c*, *t*, will give the slope of the covings, which will make an angle of 135° with it; and this is the best position for reflecting the radiant heat into the room.*

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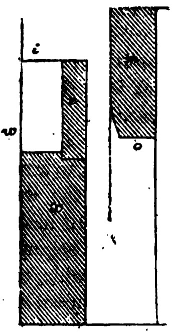
* Essays, vol. i. p. 326.

FIG. CII.



These covings, although forming an oblique surface towards the fire, are built truly upright and quite flat from the hearth or hob of the grate, as may be, to the top of the throat, where they end. The horizontal section of the throat will not be an oblong square; but its deviation from that form is not a matter of consequence, "and no attempts should be made by twisting the covings above, to bring it to that form, as all twists, bends, excavations, or other irregularities of form, never fail to produce eddies in the current of air continually flowing through a fireplace; and all such eddies disturb either the fire or the ascending current of smoke, or both, and cause the chimney to smoke; hence the covings of chimneys should never be made circular, or in any other curve, but always quite flat."*

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* Essays, Political, &c., vol. i. p. 329.

Another point of great importance is to carry up the new back, *x*, and covings, *z z*, at *least* 6 *inches above* the under side or soffite of the *mantel.*

The smoke passage or throat being only 4 inches wide, some means of enlarging it occasionally, to admit a sweeping machine, is necessary. When the wall, forming the back, *x*, is built to within 8 or 10 inches of the soffite of the mantel, *o*, an opening is begun to be left in the middle of the back 10 inches wide, and as deep as the back of the hearth recess, as shown at *i*, in Fig. CII., and carried up to the top, *i*, of the back, *x*, and covings, *z z*. This sweep door is then to be closed with a moveable tile, *e*, or piece of stone, as high as the top of the covings, and confined to its place by a rabbet made for that purpose in the brickwork. As often as the flue is cleaned the sweep removes this tile, and replaces it when his work is finished. Whatever be the material forming the new back and covings, care must be taken to fill up the space behind them in a solid manner with bricks and mortar; and where they end in the flue, on a level with the top of the tile forming the sweep door, a *horizontal* course of bricks should be laid and carefully joined with mortar.

It is of very great importance that the top of the covings and back, or where the new throat ends, should all *end abruptly*, as shown in Fig. CII. If they are finished with a slope, as in Fig. CIII., with the intention of uniting the new back and covings to the wings and back of the flue or hearth recess, this inclined coping, *a*, tends to assist the action of the wind in throwing the smoke and soot back into the room, which experience has proved does not happen when the top of the back and covings forms a flat horizontal surface. In the latter case, says Mr. Danforth, the current of hot air is determined to a particular part of the flue; and when the wind at any time forces itself down the flue, finding most resistance in the direction of this distinct column, before it arrives at the throat divides itself to other parts of the cavity, leaving a passage for the hot vapour from the throat, and is really condensed and lodged, during the blast, on the horizontal surface of the back and covings, and laid as it were on a shelf.*

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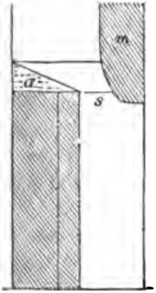
* Essays, vol. i. p. 334.

FIG. CIII.



Great care must also be to taken to give a proper form to the inside of the mantel, and unite it properly to the inside of the flue. When the height

FIG. CIV.

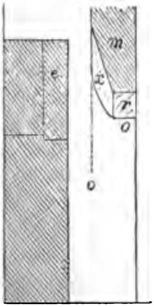
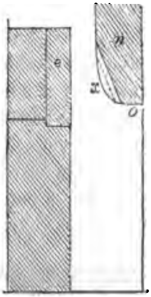


FIG. CV.



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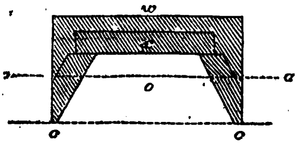
* Theory of Chimnies Investigated, p. 22.

of the mantel has to be lowered, as in Fig. CIV., where *r* is a brick arch or a slab of stone or iron bar, the slope of the inside of the breast is to be filled up with plaster, *x*, so as to form one continued flat, vertical, or upright plane surface with the lower part of the flue, taking care to round it off properly, with an easy curve to make a finish with the thin soffite of the mantel, *x*, as shown in the figure, "so that the current of air passing under the mantel may be made *gradually to bend its course upwards*, by which it will unite quietly with the ascending current of smoke, and be less likely to check or force it into the room;" and all the surfaces of the throat should be made regularly smooth. Where the mantel is of the proper height, but its flue face is built sloping as in Fig. CV., this deformity is to be corrected by plaster, *x*, as in the preceding example.

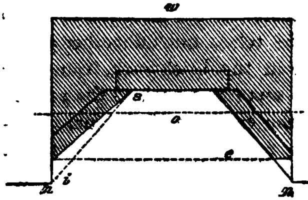
Cases will sometimes, however, occur where the hearth recess is too small to be properly proportioned to the grate and covings, and sometimes it will be too large; and it will also often happen that the fireplace must be accommodated to suit a grate already there. In the first case, 4 inches must be set off from the inside of the chimney breast, for the width of the throat, which will give the position of the fire-back; and the width of grate required for the size of the room will be the width of the back, and the covings will diverge at any angle less than 135° to the plane of the back, as seen in Fig. CVI., where *x* is the back, *a a* the line of the inside of the breast, and *c c* that of the jamb. If the recess is wider than it ought to be, 4 inches is to be set off for the width of the throat as before, and to determine the

FIG. CVI.



plane of the back; the width of which being fixed, the opening of the fireplace, when finished, is to be three times wider; if the old opening exceed this by 2 or 3 inches only, the covings may diverge at a greater angle than 135° to fill up the space; when the opening is too narrow, it is better to accommodate the covings to it than to increase its width, which in most cases is troublesome and expensive; but should the excess be greater than 3 inches, the covings must be placed at the proper angle of 135°, and the space between the jambs and covings filled up with a slip of stone or plaster. When chimneys have a tendency to smoke, the covings should be placed at a less angle to the back than in others not having this propensity.

FIG. CVII.



Another fault is commonly committed when the jambs, *c*, *n*, Fig. CVII., project some inches beyond the covings into the room; in this case, the covings are often made to diverge from the direction of the dotted line, *s*, *i*, whereas they should in *every* case slope from the corner of the jambs, *n*, *n*, to the back, *s*. The covings of a chimney should never be made to range *behind* the front of the jambs, however much they project into the room; and as a general rule, no inconvenience of any importance will arise from making the obliquity of the covings considerably less than 135°, but many cannot fail to be produced by making it much greater, an error which workmen are very prone to commit.*

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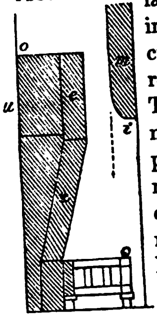
* Essays, Political, &c., vol. i. p. 349.

The grate is not shown in the figures; in placing it, the thing principally to be attended to, is to make the back of it coincide with the back of the fireplace. Should its fuel chamber be too large for the new back, and it be necessary to diminish it by filling up part of the ends and back with fire-stone or tiles, the filling-up flat piece of stone or tile, forming the new back of the fuel chamber, must be made to coincide with, and make part of the back of the fireplace. It frequently happens, that the iron backs of old grates are not vertical, but inclined backwards; the piece of stone for the new back may be made like a wedge, thicker above than below, to make the new back vertical, which will coincide with the back of the fireplace, and the iron back will be hid in the brickwork; but if the grate is not so wide as to allow the sloping back to be improved by the insertion of a slab of fire-stone, it must be taken out altogether; and fixing the grate firmly in the brickwork, cause the back of the fireplace to serve as a back to the grate.

But in diminishing the capacity of the fuel chamber, care must be taken not to make it too narrow: the proper width from bar to back of grates for rooms of moderate size, will be from 6 to 8 inches; where the width is not more than 5 inches, it will be difficult to prevent the fire from going out.

In the examples which have been given, the count considered that the chimney breast was 9 inches thick; but sometimes, in the upper rooms of a house, this part is not built thicker than 4½ inches, which would cause the grate, if it were required to be made wide, to project too far beyond the mantel. In this case, 4 inches are to be set off from the inside of the breast, *m*, the width of the throat; and if the width of the fireplace were to be 12 inches, then another 4 inches are to be set off, which will be the back of fireplace on the hearth, from which the back will slope by a gentle inclination forward as in Fig. CVIII., until it approaches the perpendicular face forming the throat. The covings are vertical as in the other forms. This slope should, however, commence at the upper surface of the fuel, and be continued 10 inches above the fire, to prevent the crossing of the current of air from the room, bringing the smoke into it. The great effect of this capital arrangement was quite unexpected. "It appeared," says the count, "to give out more heat than any fireplace I ever constructed; the back was soon very much heated, and was frequently red hot." The figure is drawn from a small fireplace, we had constructed on this principle; its performance was excellent. The width of the throat was 4 inches, the slope of the back was 4 inches forward, and it ended 11 inches above the fuel; the width of the grate was 8 inches, and its length 12 inches, and the depth of the fuel was 4 inches. The soffite of the mantel was 15 inches above the upper surface of the fuel. As a cottage hearth for small wood fires, this, from its cheapness, easiness of execution, and heat-producing capabilities, is almost every thing that can be desired.

FIG. CVIII.



The count constructed another fireplace upon the same principle, a plan of which is shown in Fig. CIX., a section in Fig. CX., and an elevation in Fig. CXI. The width of the throat was 4 inches. The fireplace was formed like a niche, and its back, *x*, was recessed 6 inches, and the grate was 13 inches long, as shown in the figures. The niche from the hearth to its crown, was 23 inches high, and it rose 7 inches above the upper part of the grate. The soffite of the mantel was rounded, and the sweep door, *e*, constructed as in the examples previously described. The jambs were also made diverging, as shown in Fig. CVII.

FIG. CIX.

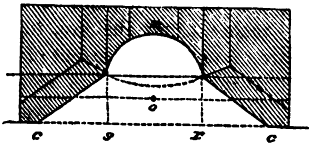


FIG. CX.

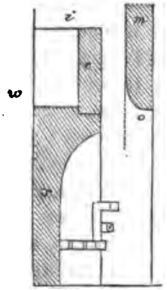
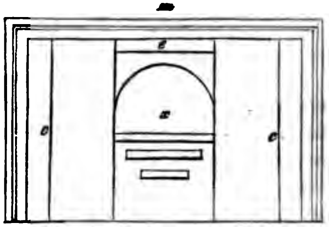


FIG. CXI.



Count Rumford's rules all proceeded on the supposition, that the velocity of the air which supplied the combustion, should be derived solely from the rarefaction produced by the incandescent mass, exposed to the open air in a grate; and that the temperature of the ascending smoke should be as *low* as possible. But when it was necessary or convenient to lower the mantel, in order to permit the smoke to rise at a higher temperature, it was found from experience that the width of the throat might be considerably reduced; and where the mantel was not more than 10 inches above the upper grate bar, it might be reduced to 1½ inches with good effect,—though with a considerable increase in the consumption of fuel.

About thirty years ago, in some parts of Ireland, the grates were long in front, and narrow from front to back, so that a large radiating surface was exposed to the room. The space above the grate was shut in by a piece of stone about 1¼ inch thick, cut out in form of an arch over the grate. The back was formed into an elliptical niche, leaving a very small opening only for the smoke to escape into the flue. Fig. CXII. is a vertical section of the fireplace; Fig. CXIII. a horizontal section from front to back; and Fig. CXIV. is an elevation; *a*, fuel chamber; *x*, niche; *m*, chimney breast; *r*, throat; *o*, slate enclosing the fireplace; *i*, termination of the throat. Mr. Buchanan, who describes this variety, gives no dimensions; but we have seen one on the same construction, in which the width of the throat was 1 inch only, and it appeared sufficient, when care was taken to feed the fire with small quantities of fuel at a time, but if the coal was thrown on carelessly, a little smoke was occasionally puffed into the room, until the fuel was perfectly lighted.

FIG. CXII.

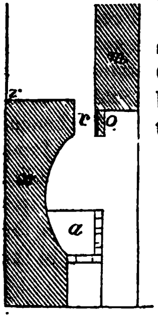


FIG. CXIII.

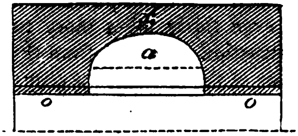
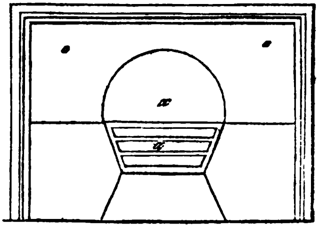


FIG. CXIV.



The effect of this construction, Mr. Buchanan says, is that the combined heat in the rising vapour, and part of the radiant heat acting on the curved back, which should be formed of fire-brick or fire-stone, heats it, and the radiant heat is reflected from its surface, as from a common mirror, while the narrowness of the throat, and velocity of the smoke, prevents a great deal of the heated air of the room from flowing up the chimney. A large portion also of the radiant heat, which in fireplaces on the common construction falls into the flue, is in this thrown upon the fuel, and acts to preserve a higher temperature in the ignited mass. "When I first observed one of these fireplaces at Belfast, I supposed," says Mr. Buchanan, "the landlord to be a man of some science; but I was surprised to find, in pursuing my journey to Dublin, and even thirty miles more to the south, that this construction prevailed from the lowest inns, to the houses of the opulent, the only difference being in the degree of ornament."*

It will, however, be apparent, that this philosophical fireplace is the same as that shown in Figs. CIX., CX., and CXI. Sixteen years before Mr. Buchanan's visit to Ireland, his friend Count Rumford had been in Dublin, and had taken great pains to explain and disseminate his principles of fire-side comfort; and it appears he had spoken to men, wise in knowing the value of good advice, and carrying it into practice. The count and Sir John Sinclair also exerted themselves to introduce the improved fireplaces in Scotland; and the Lord Provost and magistrates of Edinburgh voted a sum of money to defray the expense of sending a bricklayer to London, to be instructed by the count himself, in order to show the citizens at his return how to erect fireplaces on scientific principles; but the comparative abundance of fuel among the Caledonians, operated to prevent that attention being paid to the count's precepts, which was exhibited in Ireland and elsewhere; and perhaps they were not sufficiently advanced in civilization, to be able to put a proper value on the invention. But the improvement may be said to have created an expression of applause and satisfaction, from one end of England to the other,* or as a "bard" expresses it,—

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* Treatise on the Economy of Fuel, p. 316.

"Note of melodious cadence on the ear—
Loud echoes Rumford here and Rumford there.
Lo! every parlour, drawing-room, I see,
Boasts of thy stoves and talks of nought but thee.
Yet not alone my lady and young misses—
The cooks themselves could smother you with kisses.
Yes, Mistress Cook would spoil a goose or steak,
To twine her greasy arms around thy neck."

Yet it is not to be imagined that they thus—

"Expressed in gratitude their souls
To him whose wisdom saved us pecks of coals,"

—merely on account of the money value of the saving of the heat-giving fossil; but from feeling that, in their case, economy in fuel prevented a frightful waste of invaluable life.

The pleasure of refined and excessive eating is of the most ancient origin; but Epicurus, whose name has been given to the species gourmand, disdained excess and costly entertainments, and fed sweetly on bread and water. Modern Epicureans despise his practice. Their belly, which, according to Bishop Taylor's admeasurement, is not a span long, is their God, for whom numberless ovens, furnaces, and raging fires must be provided to combine the propitiatory offerings from all corners of the earth, air, and waters. Under the burning influence of these bonfires the temper of priests and priestesses of the palate, ministering in the preparation of the convivial sacrifice, is as short and irritable as that of an eel undressing for the stewpan; while, as Beresford has it, they look and feel like buttered mummies; and it has always been a subject of unmitigated regret that these personages, whose exquisite and sublime talents are consecrated to give a savour to existence, these creators of unspeakable pleasures, should, from devotion to their divine art, be cut off in great numbers by apoplexy and asphyxia, and that almost all of them should die very miserably.

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* To enable future topographical historians to point out with certainty, and attach due importance to the spots where this celebrated contrivance was first exhibited, it may be stated that the first experiment in London was made in Lord Palmerston's house in Hanover Square, and then in his house at Broadlands. Rumford fireplaces were in succession erected in some rooms of the Board of Agriculture—in the house of Sir Joseph Banks—in Devonshire House—in Melbourne House—in Lord Besborough's mansion at Roehampton—in Lady Spencer's villa near St. Alban's—in Lady Templeton's, Portland Place—in Mrs. Montague's, Portman Square—in the houses of Lord Salisbury in London and Hatfield; and shortly afterwards in thousands of others.

Count Rumford's conservative philosophy is seen in no fairer light than in his endeavours to ameliorate the melancholy fate of these meritorious professors of culinary science; and when he showed that thick substantial soup, which had been stewing for five hours, and was sufficient to form a meal for three thousand persons at a pint a piece, could be cooked with sixpence worth of coals when they were selling at twenty-three shillings a ton, it is beyond all doubt that none of the heat evolved from this fuel could have escaped to fall on and annoy the culinary chemist. In many kitchens constructed under the count's directions, in which roasting, baking, frying, broiling, steaming, stewing, and boiling, were going on at the same moment, the heat that had formerly made the artists fret as much in their own grease as the viands they were basting, was so admirably confined to its own particular and especial purpose, that the count usually made provision for a hearth with its flue, on which in cold weather a fire might be made to warm the angelic cookey while engaged in superintending all these incomparably interesting processes.

If the merit, therefore, of an inventor should be estimated by the wide spread good that may be produced by his inventions, most laudable that enthusiasm must be considered which inspired the poet to tell the count—

"Immortality is sure;
Long as thy chimneys shall thy praise endure.
Aloft ascending, lo! thy radiant fame
With thy own curling clouds of smoke shall rise
And sunlike give them lustre in the skies."

Nothing can be more simple and plain than the directions left by this great man to guide posterity in the construction of chimneys, yet not more than thirty years after his death, with shame it must be spoken, scarcely one fireplace in ten thousand is formed agreeably to his formula. All, it is true, have *sloping covings*, and on that account all are said to be "Rumfordized." Even circular covings and a perforated register plate, both of which were the count's utter horror and aversion, now confer the same popular title. The essential part of his invention was, however, the formation of the throat, and the advanced position of the chimney-back with regard to the room. Without attention to these points, sloping covings are mere delusion, and cruel satires on the fair fame of Count Rumford.

Mr. Danforth, a countryman of the count's, notices the use of sloped covings in early times in America. There, wood being plentiful and labour high, it was usual to cut their fire wood from three to six feet long. This required a large fireplace;

and accordingly they were generally built so, even in the best rooms in good houses, many of them in the same manner as the fireplaces in the country in England, with a seat on each side-wall or jamb, and the whole was generally whitewashed. Now, continues Mr. Danforth, as wood makes much more blaze, and warms much more at a distance, or sends out more radiant heat than coal, probably from the lesser density of its texture, it naturally happened that the tendency of these white walls to reflect the radiant heat was noticed and found to be considerable in America, while the dull coal fire in England never had given that intimation. Accordingly, as wood became less plentiful, the propriety of reducing the fireplace became obvious. They then built a small fireplace within those large ones, and conforming in part to the old practice, kept the front still wide, but narrowed them more at the back: this answered the purpose of allowing the sight and the direct influence of the fire to a greater number of persons; "and at the same time," says Mr. Danforth, "those diverging sides, which obtained the appropriate name of *flaring-jambs*, being still kept white, reflected the radiant heat more completely into the room. If this expression is known in England, it must have been carried over by the first settlers. These jambs however, by whatever name they may be called, I have seen in England; and no doubt there are many instances of a small fireplace built within a larger one, and in general the whole construction as described by the count, but perhaps in no instance to so much advantage—nor were they so well constructed, in America the throat being seldom so small or the fireplace in general so much reduced."* That is, however, saying that there was a resemblance, but no similarity.

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* Theory of Chimnies, p. 18.

At the period the count wrote, the construction of the flues was not so carefully attended to, as they are now, and improvements were as often welcomed and valued as remedies for the defects of smoky chimneys, as to throw the greatest quantity of heat from the fuel into the room.

It was with this view that Mr. Danforth propounded what he considered to be an improvement on the Rumford fireplace. The lower part of the fireplace is to be built as directed by the count; it is then to be continued upward, from a little above the mantel bar, by the back and sides *converging* or being brought toward each other, and the breast also, by running an iron bar within it and a little higher than the mantel bar, and so all around to lay the bricks upon; and the four sides are thus to be continued upward, approaching each other until the throat be just left sufficient to admit the cleaner. A little internal chimney is then to be continued considerably higher by running up a large iron or tin tube from 6 to 12 inches in diameter, this tube should fit the throat as closely as possible, and be supported in its place by two small bars running across under its lower end, and loosely let into the brick-work at each end, which may be taken out when the internal funnel is to be removed to clean the chimney. There will then be a vacant space all round the internal chimney as far down nearly as the mantel bar. When the funnel was properly proportioned, a chimney in which this construction was adopted had no tendency to smoke, when the wind blew from any quarter or with whatever violence, and the room was perfectly warmed.* This arrangement deserves Mr. Danforth's encomiums. If numberless pipes that disfigure the chimney tops of our houses were removed and placed in the situation of this internal chimney, the exterior would be improved, and the smoke more effectually prevented from coming into the chamber.

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* Theory of Chimnies, &c., p. 25.

The hot air fireplaces that were constructed by Mr. Sharpe and others were nearly the same as those which have been described in our Tenth Essay; but with a contracted throat furnished with a valve or damper. Fig. CXV. is a section, and Fig. CXVI.

FIG. CXV.

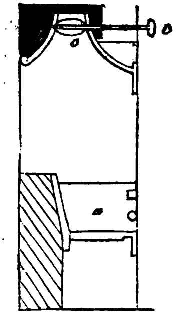
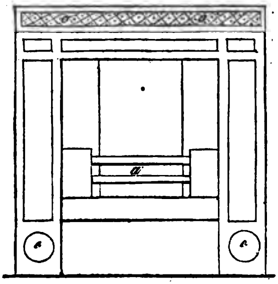


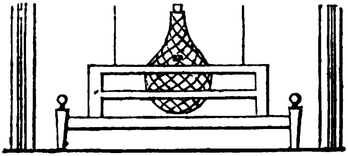
FIG. CXVI.



a view of one of these fireplaces; *a*, is the fire-box; *b* the register; *c*, its valve; *e*, *e*, two apertures into which the air of the room was supposed to enter, and coming into contact with the heated sides of the fireplace, sometimes formed with meanders, was warmed and emitted again into the room at the holes, *o*, *o*. In many cases this was a clever improvement, but it got out of fashion from sometimes burning the air; but more frequently from producing small effect through injudicious construction. It differs little from many fireplaces in present use, except in the decoration.

Fig. CXV. is another variety of stove then recommended as a smoke curer; *a* being a sort of æolipile filled with water, and forming the back of the fireplace, was kept boiling; and the escape of the steam from a small hole in its narrow neck "drove the smoke up the flue": and in cases where economy was studied, was recommended as having power to drive a smoke jack at the same time.

FIG. CXVI.



About the same period, Mr. Smith produced what he called the "Retiring Grate," which was constructed to be drawn outwards to a certain extent like a drawer, when more heat was required, and pushed back into the hearth recess when the air was warm enough, or for safety when the inhabitant left the room. The idea is one more worthy revival and extension than a crowd of useless things which have since been presented as inventions to the public.

Mr. Blundel's improvement was confined to the fender. The top of this was made of wire work, sloping from the under bar of the grate to the front of the fender. The cinders, falling on this grating, rolled down to the lower part in front, where they were collected, but the ashes fell through into a box on the hearth.

The fireplace most esteemed was Moser's. It had porcelain tubes placed on the sides and back, in which the air was heated, and the burnt odour prevented that was produced in others, as it was thought by coming in contact with the hot iron; but the improvement was a departure from right principle.

All the heat communicated by the incandescent fuel to the metallic covings and back of the fireplace should have been imparted to the room by a greater quantity of air being made to impinge upon them, and absorb the heat—the porcelain tubes reversed this. Hot air fireplaces were at this time very expensive, which totally hindered their good effects being experienced in rooms used by the lower classes, where they would have been truly beneficial, and with a trifling alteration also very economical.

Some of Mr. Moser's grates were admired for tasteful decoration, but perhaps the most elegant fireplace was that contrived by Mr. Burns, which had the form of an open elliptic vase placed in a circular niche, of which Fig. CXVII. is a ground plan, and Fig. CXVIII. a vertical section from back to front; the oval vase, *a*, containing the fuel, had a bottom grating like the ordinary parlour grate. Air from the outside was admitted by the channel, *e*, and flowed into the base of the grate, and thence into the enclosed ash-pit, as indicated by the arrows. This passage could be opened or shut by means of a valve placed where the channel, *e*, joined the vase. But the hissing

FIG. CXVII.

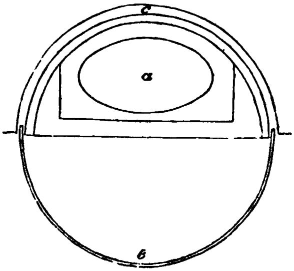
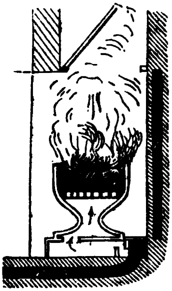


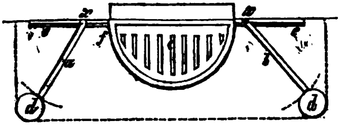
FIG. CXVIII.



noise produced by the flow of air in certain circumstances, was an objection; and, as the grate was open on every side, it was difficult at times to produce a perfect combustion of the fuel, and keep the fire alive. It is noticed here for exhibiting the first attempt at combining a safety screen with a fireplace. A circular groove, *c*, was formed behind the back, which enclosed a circular fender, *e*, that was drawn forward when required into the position shown by the circle, *e*, in Fig. CXVII. The screen was filled with glass or wire-work, and the mantel had a circular form also.*

Mr. Ralph Dodd's fireplace was, in effect, a return to the ancient cottage chimney, reduced in dimension, to which he added moveable reflectors *a*, *b*, which were the whole height, from the floor to the mantel. They had a vertical joint at *x*, and a lateral movement from and towards the fire at *c*, in the direction of *f*, *e*. The reflectors could therefore be placed at different distances from the fire, and also at different angles, to suit the comfort or convenience of persons sitting round it. The chimney breast was supported by slender iron pillars; but the appearance of the whole being considered *outré*, it was neglected.

FIG. CXIX.



In Mr. Peale's American fireplace, the mantel was moveable. It had a door or shutter in front, suspended by pullies like a sash window, which was raised or lowered to increase or diminish the distance between the fire and the throat, as now practised in ships' stoves. An English stove doctor, whose name we have forgotten, adapted this shutter as a fireguard, by forming it of wirework or glass. It was partly with the same intention of avoiding accidents by fire, that Mr. William Clerk placed a stove-like grate, with an open door, in the hearth recess, and enclosed it with a sort of window formed of metal bars, fitted with panes of glass, and set at 10 inches' distance from the front of the grate; the glazed frame was moveable and slid in a groove. Air to supply the fire was drawn from the outside or from an adjoining room, but not from the apartment, and the smoke was carried by a pipe into the flue. Mr. Clerk thought that the room would be warmed partly by the radiant heat from the surfaces of the stove, which he erroneously supposed would be propagated through the glass, and partly by the air heated in the enclosed recess, by contact with the insulated surfaces of the stove, which was admitted into the room by opening the screen. No smoke or dirt or sparks, Mr. Clerk says, could be thrown into the chamber, and the view of the fire was as cheerful as if it were not enclosed. As the inventor himself, who was a Scottish advocate, was perfectly pleased with his invention, it may be allowed to have performed its office.

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* Philosophical Mag. vol. v. p. 267.

No method had been devised for supplying the fire with coal, except by the clumsy method of throwing it on the upper surface of the burning fuel, from a shovel or coalscuttle, until Mr. Cutler described the mechanism, of which Fig. CXX. is an elevation; Fig. CXXI. a horizontal section; Fig. CXXII. a vertical section, taken from front to back. In all the figures, FIG. CXX.

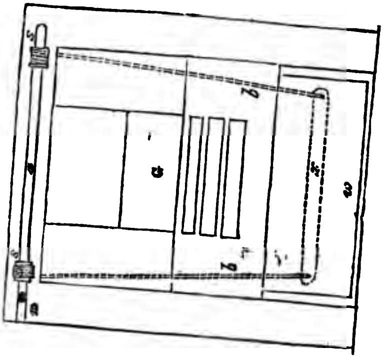


FIG. CXXI.

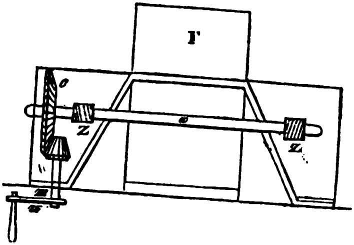
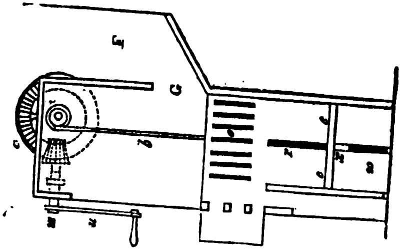


FIG. CXXII.



the same letter is placed on the same part; *a*, is an iron box, formed by the back and two sides of the fuel chamber being continued down to the hearth, and the fourth side, or that towards the room, rising as high as the under bar of the fuel chamber. A long slit, *r*, is made in the two sides of this box, from within an inch of the bottom or hearth to the level of the under grate bar. A thin horizontal bar, *x*, about 1 inch in depth, is inserted into these side slits, and projects about 2 inches beyond the sides; to the upper side of this bar a plate of iron, *e*, is attached of the size of the iron box. To each end of the horizontal bar, *x*, was affixed a small chain, *b*, which was wound on an iron axle, *a*, on which was fixed a wheel, *c*. The axle was supported in the usual manner by brackets, which are not shown in the figure, to prevent crowding it. The wheel was moved by a bevel wheel, the axle of which was hollow; into which the pipe of the crank was inserted; *a*, the bars of the grate; G, opening for the smoke into the flue, and *o*, slits in the sides of the fuel box to admit air. The operation is thus:—Coals sufficient for a day's consumption put into the iron box, rest on the iron plate, *e*, attached to the horizontal bar, *x*; a fire is lighted in the usual manner on the top of this fuel; as the fuel consumes, and more is to be supplied, by turning the crank the bevel wheel gives motion to the spur wheel, and the revolution of the axle, *a*, winds up the chains, *b*, attached to each end of the horizontal bar, and of course raises the iron plate attached to it, on which the coals are placed; and this as often as is thought convenient. The coal is thus supplied from the bottom under the ignited fuel, and smoke in a great degree prevented.*

Fig. CXXIII. shows the mechanism, by which the moveable bottom of the coal box was prevented descending when loaded with the fuel. When the coals were to be raised, the pipe of the crank was inserted into the hollow axle, which pressing a lever forward on a spring, disengaged a catch on the bevel wheel, and permitted the wheel to revolve.

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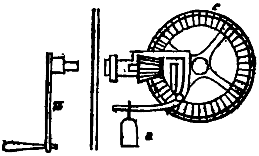
* Repertory of Arts, vol. ii. p. 170.

FIG. CXXIII.



The practical objections to this apparatus were a supposed defect of air to supply the combustion, as none could ascend through the coals in the box; and the difficulty of keeping the fuel clear of ashes. In some fireplaces, Mr. Cutler got rid of both objections, by making the grate bars project in the manner shown by the line in the vertical section in front of the bars.

This elegant and ingenious mechanism involved its inventor in a lawsuit, in which the quibbles of his piratical and mercenary rivals in trade prevailed over the fairest claim to the protection of a patent.* This was demolished, and the probable future improvement of the mechanism was lost to the public.

Another contrivance to introduce fresh coals under the ignited fuel, was to make the lower bar of the grate so that it could be raised on a joint. The coals to be added were placed on a shovel, which was then inserted under the moveable bar; and they were pushed forward into the fire by a sort of piston contained in the handle of the shovel.

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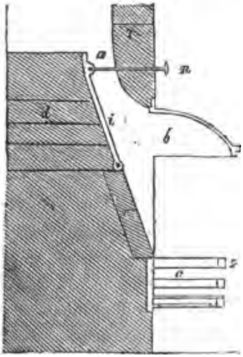
* Stuart. Historical and Descriptive Anecdotes of Steam Engines, p. 641.

The practical objection to the fireplace described in page 32, and which Dr. Franklin named the Staffordshire grate, from having seen it used in that district, was its tendency, from a partial deflection of the column of smoke by any sudden motion of the air in front of the fireplace, to bring the smoke and dust into the room. Mr. Meikleham, in 1822, described a modification of this excellent apparatus, by which this defect was in a great degree corrected, without sacrificing its other advantages.

Fig. CXXIV. is a vertical section from front to back of the social grate; Fig. CXXV. an elevation; and Fig. CXXVI. a plan. The opening of the hearth recess is closed up on a line with the face of the breast wall, and an opening never exceeding the width of the flue is made into it from the level of the upper grate bar, and the fire is wholly within the apartment, and outside of the hearth recess. —The bottom grating is 5 inches above the hearth, the depth of the fuel box, *c*, is 4 inches, and its width from front to back 8 inches; the length of the grate in front 12 inches; the distance between the upper grate bar, *z*, and the under edge of the canopy or hood, is 12 inches; which projects an inch beyond the bars, and rises 4½ inches.

FIG. CXXIV.



The back of the fuel chamber lines with the wall of the room. The throat, *a*, 3 inches wide, has a register, *i*, by which it may be diminished to 1 inch; but the best effect will be produced, when placed to make the opening 1¼ inch. Besides preventing the puffs of smoke coming into the room when the fire is first lighted, and occasionally when fresh fuel is hastily thrown on in too great quantity, radiant heat is absorbed by the hood, and the air coming in contact with its upper surface is warmed, and spreads into the room.

FIG. CXXV.

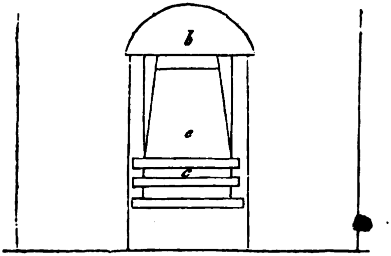
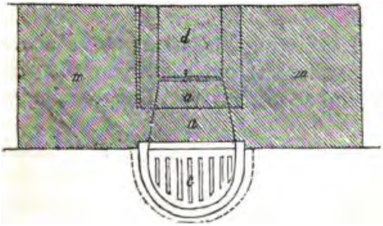


FIG. CXXVI.



The hood should be made of cast or wrought iron, and it is of importance to give it the concave form shown in the figures—a flat surface was found to be improper. The inclined sole, *e*, should be made of a fire-brick, and the covings also of fire-brick or stone, and the fuel basket may be fixed into the brick-work in the common manner. The hood, *b*, may be made to be put on or taken off. In cottages the space at the back of the fireplace may be converted into an oven, with a door at the side of the fuel basket, or the fuel basket itself may be hinged so as to open or shut like a door.

This description of fireplace would be useful in upper stories, in cases where it is often difficult to get a hearth recess of the common size, on account of the space occupied by the flues of the under stories. In this construction a hearth recess is not required. In cottages, also, were the flue continued to the hearth, it would be a saving in the first cost of building.

A fireplace having dimensions stated above, comfortably warmed a room containing 1630 cubic feet of space, and 30 feet superficial of glazed opening.

FIG. CXXVII.

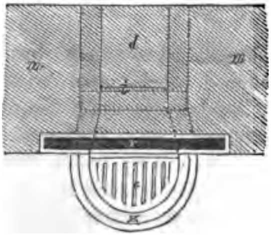


FIG. CXXVIII.

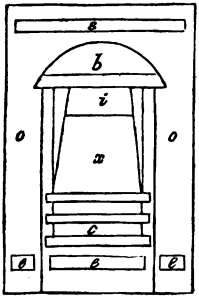
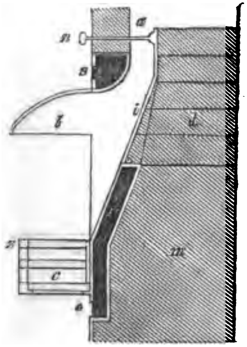


Fig. CXXVII. is a plan; Fig. CXXVIII. a section, and Fig. CXXIX. an elevation of the same fireplace, with a hollow back and sides for introducing warm air into the room; the interval, *x*, into which the air is admitted, must not exceed 2 inches, but in general 1½ inch would be better; one side of this interval may be brick or stone, formed by the face of the filling in, *m*, if an iron plate be considered too expensive. When the flue is to be cleaned, the register plate falls back into a recess, *d*, left in the brick-work, *m*, the filling up of the old hearth recess. The fresh air may be admitted at bottom, into the space, *x*, either from a pipe or channel opening to the external air; and as it rises upwards, it will come in contact with the heated back and sides of the fireplace, and be emitted into the room at the aperture, *s*, which is furnished with a regulating slide valve. The width of the throat, *a*, is adjusted by the register, *i*. The area of the apertures for the admission and emission of the cold and warmed air should each be equal to the area of the throat of the fireplace. Should it not be desirable or convenient to bring the external air into the heating channels, openings from the rooms may be made, at *e*, *e*, into the back at *x*, and a circulation of warmed air will be produced in the apartment.

FIG. CXXIX.



In a case where it was thought 4 inches a sufficient projection into the room, the fireplace was formed as shown in the plan, Fig. CXXX. and section, Fig. CXXXI. The bottom of the fuel grate was 4 inches above the hearth, and the fuel basket, *c*, was 5 inches deep, and 8 inches from front to back, with the recessed portion, *o*, curved as shown in the section.

FIG. CXXX.

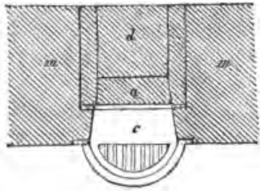
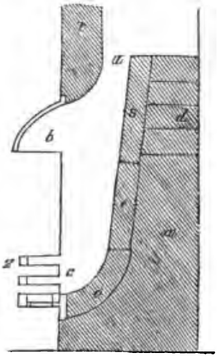


FIG. C XXXI.



The height between the top of the upper grate bar, *z*, and the under edge of the canopy, *b*, was 12 inches; the throat, *a*, 2½ inches wide, and 6 inches long. The concave part, *o*, of the bottom of the fuel chamber, and the fixed part, *e*, of the back, were of fire-bricks filled in solid behind; *s*, a moveable tile or stone that is taken out when the flue is cleaned; *d*, a space behind it, to admit the sweeping apparatus, which is sometimes left open at top, but it is better to be filled with loose bricks, that are taken out and replaced along with the tile, *s*.

In a counting house, in which this fireplace was placed, its heating properties elicited great approbation. Another was fixed in a bedroom, and there it also became a great favourite. A small damper, drawn backward and forward by a spindle going through the breast, *x*, to diminish the area of the throat, is omitted by mistake in the cut. After the fire burned clear the throat was usually diminished to have a width of half an inch only.

Another form of the same fireplace without a hood, which has been named the Connisborough hearth,

FIG. CXXXII.

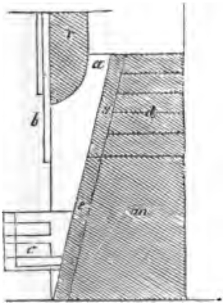
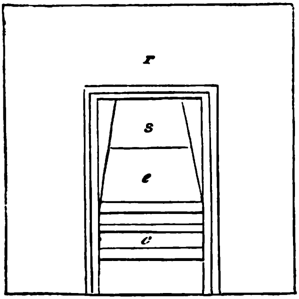


FIG. CXXXIII.



is shown in section, Fig. CXXXII., and elevation, Fig. CXXXIII.; the fuel box was placed 4 inches above the hearth, and was about 3 inches deep, 8 inches from back to front, and 12 inches wide, which was the width also of the flue. The soffite of the mantel was 14 inches above the upper surface of the fuel, and the throat 3 inches wide and 7 inches long. The performance was uniform and satisfactory, and the combustion of fuel did not appear to be excited by any lateral communication of motion from the current in the flue. It had an iron valve, *b*, like the register of a ship's stove, which could be lowered to bring the stream of air nearer the surface of the fuel when required. This was found a very useful addition.

Mr. Marriot's fireplace has the novelty of a receptacle, containing a supply of fuel, and adding it under what may be ignited in the fuel box, to answer the same intention as Mr. Cutler's. Fig. CXXXIV. is a section of this apparatus, and Fig. CXXXV. an elevation. The cuts will sufficiently explain its construction. The charge of coals is put in at c, and the

FIG. CXXXIV.

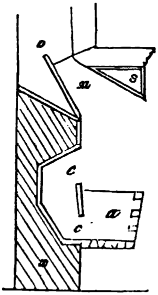
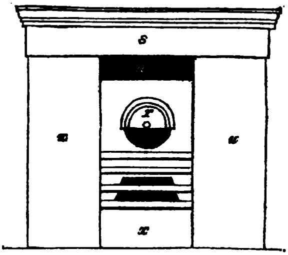


FIG. CXXXV.



door, *r*, is then closed by turning it with a screw winch. When coals are to be added they are stirred forward by a crooked poker from the coal chamber, *c*, which opens at bottom to the fuel basket; *n*, is a register for regulating the size of the throat; *s*, a projecting canopy which was formed hollow, and into which the cold air was admitted and heated, and flowed through a valve into the room. This grate had a fender of peculiar contrivance, and an apparatus in which the air was condensed, and then conducted by a pipe with a cock to blow the fire. All of which, with the exception of the coal chamber, however, are more ingenious than useful.

In the long list of fire-grates that are recommended by manufacturers, the greater number vary in their pattern only. Mr. Sylvester's is, however, an exception which exhibits considerable novelty of construction. Fig. CXXXVI. is a vertical section, and Fig. CXXXVII. an elevation: *a*, are radiating iron spokes raised a little from the hearth, *b*; the narrower end of these spokes form the bottom of the fire-chamber, *c*, beneath which is the ashpit, *d*, made large enough to contain the ashes produced during several

FIG. CXXXVI.

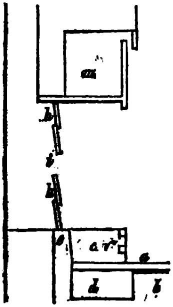
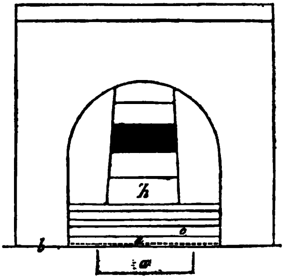


FIG. CXXXVII.



days. The back, *e*, of the fire chamber, is formed of a fire-brick; the continuation of the back, *h*, is fitted up with a series of small shutters, arranged like luffer-boards, all of which are moveable; and by removing any of these the draught of the chimney is regulated. In the section, the third luffer is supposed to be open; when the lower luffer plate is taken out, the apparatus is to all intents and purposes a Staffordshire grate. The fireplace has the great advantage of being insulated from the walls of the hearth recess, and the air in the space *m*, which is warmed by coming in contact with the iron work, is allowed to flow into room. The radiating rods are an elegant substitute for the common hearth, but perhaps are of no further use.

A fireplace, described by Colonel Pasley as the contrivance of Captain Sandham, has been introduced with great advantage into the barrack rooms at Brompton. Fig. CXXXIX. is a horizontal section; Fig. CXL. is a vertical section from front to

FIG. CXXXIX.

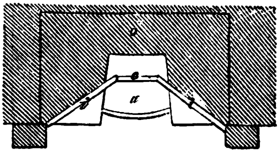


FIG. CXL.

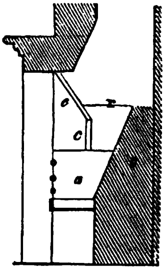
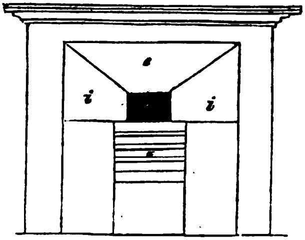


FIG. CLI.



ack; and Fig. CXLI. is an elevation. The smoke opening, *c*, that is placed on a level with the hobs, is 9 inches long and 6 inches high. The covings, *e*, *i*, are formed of paving tiles a foot square, cut to the required splays; and one of these tiles, *e*, over the centre of the throat of the chimney, is made to take out, being placed dry, and the joints towards the room not flushed, but only pointed with cement, so that it is moveable when the chimney requires sweeping. Of all the fireplaces that have been Sandhamized properly, only one, it is observed, still smokes in westerly winds. Compared with Count Rumford's system, the Colonel says that he considers the top coving of the Sandham fireplace "a great advantage, inasmuch as it brings the throat of the chimney nearer to the fire, without the inconvenience of allowing too much of the heated air (from the room?) to pass up the flue. Instead of which it throws out more heat into the room than when the back is upright, as every one acknowledges who has been in the same rooms before and after the fireplaces were Sandhamized." *

It will, however, be apparent that this fireplace has not the slightest affinity with those of the immortal Count. His grand object was to keep the throat as far from the fuel as possible, instead of bringing it to the surface of the fire as Captain Sandham does. The whole apparatus is what may be called a hybrid Staffordshire fireplace, without the advantage of its advanced position in the room. And the greater heat thrown out, should be referred to a more rapid combustion of the fuel, in consequence of the increased velocity of the current of air sweeping through and over the fire; but then, this is attained by a greater consumption of the combustible.

In improving the barrack fireplaces the Colonel observed the importance of the Count's rule, "that after reducing the throat of a chimney the work should terminate *abruptly* a little above that level." The bricklayers, in two or three instances, thought proper, of their own accord, to slope up both the back and sides above the throats of the Sandhamized fireplaces in order to make a neater finish, and also from a natural desire to make it stronger; and they thus produced that sort of trumpet mouth, (shown in the cut, Fig. CIII.,) above the throat of the chimney, which the Count reprobated; in consequence of which those fireplaces continued to smoke a little; but on removing all the extra filling in, so as to restore abruptly the large rectangular opening of the original brickwork, forming a sort of gulf immediately above the throat of the chimney, this evil was remedied, and none of these chimneys now smoke, even in the most violent gales of unfavourable wind, excepting by small puffs, occasionally on lighting the fire, which cease when it burns clear.*

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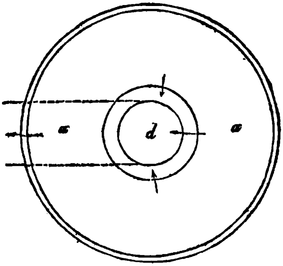
* Papers on Subjects connected with Corps of Royal Engineers vol. ii. p. 67.

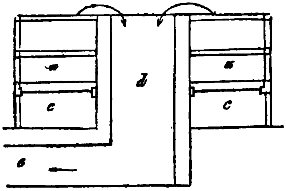
An elegant, complex apparatus that operated by the reversed flame, was described a few years ago by Mr. Mallet. The Edinburgh fireplace is a more recent contrivance on the same principle, but simpler.

FIG. CXLII.



Without smoke or dust, and perfect in its form for the diffusion of radiant heat, if placed where all hearths should be, in the centre of the room, it would form

FIG. CXLIII.



in a manorial hall, the ne plus ultra of a fireplace. It is shown in plan. Fig. CXLII., and a section, Fig.

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* Papers, vol. ii. p. 68.

CXLIII.: *a*, circular fire-chamber, *d*, smoke flue, communicating with a vertical chimney flue; a draught is produced in this flue by the usual means, which carries the vapour from the coke fire, downwards into the circular flue, *d*, and thence into the chimney flue, *e*.

There is a kind of fireplace, now very prevalent, which has an appearance of snugness and comfort, but without the reality of either. The fire-chamber is buried in the hearth recess, no means are provided for the adjustment of the throat, and much of the reflected heat is lost. In many districts the smoky rooms in cottages have fireplaces like that in Fig. CXLIV. and Fig. CXLV. The covings are Rumfordised, and the throat is left of any dimension. This and all similar forms are only *revivals* of the celebrated Bath fireplace, which is described and figured in p. 22.

FIG. CXLIV.

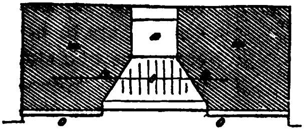
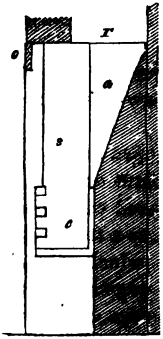
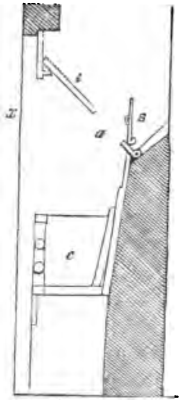


FIG. CXLV.



Another very common form of fireplace is that shown in Fig. CXLVI. Here all is enclosed, and the throat is diminished by an opening, *a*, left in the register plate, *i*, which is also generally fixed with a hinged valve. Sometimes hobs are provided, and the opening of the fireplace or under edge of its mantel is at a distance of 16 or 18 inches from the fuel;

FIG. CXLVI.



but then the smoke door, *a*, is seldom more than from 6 to 8 inches above the upper surface of the fuel, as shown by the dotted line, *x*, which places all such in the category of the Staffordshire fireplace, and requires careful regulation of the smoke valve to prevent a waste of fuel. These sort of grates, with the smoke aperture placed near the fire, and also that shown in the previous cut, being but *wolves in sheep's clothing*, are to be eschewed by every one who studies economy in coals. Warranted smoke-curing grates, for which advertising smoke-doctors require no pay if there be no cure, are all constructed on the principle of bringing the air that flows up the chimney near the surface of the fuel—or, in other words, by making them furnaces; but in none of them is due attention paid to the formation of a proper throat, and to the regulation of the draught, and their effect is therefore produced with a great waste of precious fuel.

A glance at some of the circumstances that affect combustion will show other points in which these and most fireplaces are defective.

In a mass of fuel, burning in an open grate of any description, some of the external parts are black or dark—others in the interior are covered with an ashy substance, beneath which the coal has a feeble glow; some portions are at a dull red heat, which passes by numerous gradations into an orange-tinged and almost colourless light, so dazzling that the eye can scarcely behold it: the jets of flame are of intense brightness, and every moment all parts of the heated mass vary in brilliancy, as if they were swept by waves of light. The colours change with the intensity of the heat. Bodies become visibly red hot in a dark place about 650°. At 800° they are obscurely luminous in the light; a dull red heat visible in broad daylight is placed between 1000° and 1077°; a bright red at 1200°, and an orange-coloured red at 1650°. The flickering, yellowish white, incandescent, gaseous matter has a still higher temperature. During this emission of light and heat, the fuel gradually loses its solid form, dissolves as it were in the air and disappears; and when the combustion ceases, a small quantity of ashes, about one or two parts in the hundred, is all of the coal or charcoal apparently remaining.

The evolution of light and heat always accompanies a chemical union of the oxygen contained in atmospheric air with the carbon or pure charcoal, and its compounds with hydrogen, which form the greatest part of the substance of the fuel. The oxygen in the fuel varying from 3 to 14 per cent. perhaps diminishes the quantity abstracted from the air; the nitrogen which forms 75·5 per cent. of the air, and from 4 to 16 per cent. of the fuel, suffers no change.

Before, however, this union can take place, the fuel must be raised to a temperature between 750° and 800°. The red hot carbon then attracts the oxygen from the atmospheric air in contact with it, and the compounds of carbon and hydrogen require a still higher temperature to unite with the air and evolve flame. These combinations are the main source of artificial heat for domestic purposes, and their ultimate products are carbonic acid gas, nitrogen gas, and the vapour of water. Nitrogen is incombustible, and carbonic acid gas extinguishes burning substances of all kinds, not from a want of oxygen only, but from exerting a positive influence in checking combustion.*

Different kinds of fuel require different quantities of atmospheric air for their combustion: a pound of coke will require as much oxygen as must be abstracted from about 157 cubic feet of air; a pound of common Newcastle coal would require a still larger quantity of air.

To produce perfect combustion all the air which comes in contact with the fuel must be decomposed, and have the whole of its oxygen abstracted. Should any portion escape this process, it will be injurious in proportion as its quantity exceeds that which has united with the fuel. Each successive portion will carry off the heat from the ignited surface, until its temperature is reduced below that at which it can abstract oxygen from the air and continue its action; the combustion then languishes, and by degrees is extinguished. It is also essential that this air should be pure and free from mixture with the gaseous products of the combustion. In proportion as it is mixed with them will its chemical union with the fuel be impaired or prevented. The higher the temperature of these solid and gaseous matters, the more rapidly they will decompose the air in contact or mixed with them; and the more rapid the combination, the greater will be the quantity of heat and light evolved. As the excess of the heat produced exceeds that which is absorbed by the fuel to maintain its combustion, the greater will be the quantity radiated into the room, and combined with the gaseous vapour or smoke. It is only, perhaps, when bodies combine rapidly that this excess is considerable. When the process has been slow, the total quantity of heat extricated may be the same, but it never accumulates in sufficient quantity to constitute fire, which only appears when heat is concentrated to a certain degree in the luminous body. Hence the loss of effect when fuel in an open grate smoulders and consumes at a low temperature.

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* Turner. Elements of Chemistry, p. 286.

The art of using fuel to the best advantage in open grates, is to maintain the whole mass in a state of vivid incandescence, by preventing all unnecessary abstraction of heat from the burning hody—either by currents of cold undecomposed air flowing over it, or by its contact with solid or liquid bodies which are good conductors—for it is obvious a fire may be as effectually extinguished by contact with a solid body that may be rapidly cooled, as by a stream of cold air. The necessity of exposing a large portion of the incandescent surface to the atmosphere, makes a due regulation of the quantity of air admitted to it almost impracticable; and in an open fire, all that can be attempted, in order to preserve the temperature of combustion, is to ignite a greater mass of fuel than would otherwise be required, and by partially excluding the air from the back and sides to lessen the surface exposed to the refrigerating influence, with the loss, however, of the radiant heat that surface might have emitted.

Where fuel, which contains little or no bituminous matter—such as anthracite, or Kilkenny, or Welsh stone coal, or coke—and which requires a high temperature to be retained in the entire combustible mass, it is found very difficult, from the cooling effect of air, when burned in small quantities in an open grate, to keep the external surface incandescent, and the fire alive; and as the heat radiated from the exposed surface is very small, Mr. Bull recommends the common open bars of the fuel chamber to be discarded, and the front of the fire to be enclosed by a thin plate of iron which would not be less agreeable than the equally sombre aspect of the unignited coal in front of the generality of small grates, particularly as the top of the coal would present a more luminous appearance to the room. Although iron is a good conductor of heat, the plate would be sufficiently heated to maintain the temperature necessary to carry on the combustion of the surface exposed to it, with the exception of the points which actually come in contact with it; and it would prevent the ingress of air into the spaces among the fuel. If there was a danger of melting the iron in this situation it might be coated in the inside with clay, or lined with brick. The ash pit also should be enclosed and have a door for the removal of the ashes and a valve by which the necessary quantity of air might be admitted without any excess. This construction would also be favourable for heating the air which enters from beneath to supply the combustible, the advantage of which is most obvious, when the necessity of cooling the burning body as little as possible is considered; the apparatus besides would be more cleanly than an open grate, could be made use of for culinary purposes, and would radiate a great deal more heat.*

The same judicious stove doctor observes, that in grates for using this coal, it is objectionable to make the receptacle for the coal of greater length than it has breadth or depth, by which the body of coal is not as much heated, and requires to be replenished more frequently to maintain the relative position of the coal necessary to continue the combustion. A much better shape, and which would require less coal at any one time, would, he thinks, be in the proportion of 12 inches deep to 8 inches square at top, and gradually diminished to 6 inches at bottom, by which the heat generated in the combustion of the coal at the lower part of the grate, in its passage to escape at the chimney, would come in *contact* with nearly the *whole body of the coal,* and keep it heated, which cannot be the case in the former shape, supposing the content and the coal in each to be equal; and in the case of their being only *half filled* with coal, the position of that in the *deep* grate will be very favourable for combustion, while that in the shallow grate, would scarcely burn at all. The advantage of placing the body of the coal in a deep grate, he illustrates by the well known fact, that a stick of wood burns much more rapidly in a vertical than in a horizontal position. But here Mr. Bull seems to have been led into error, by an apparent instead of a real analogy. The flame on a long stick, is supplied in its whole length with pure air; but when a deep mass of fuel is enclosed in a grate or stove, the carbonic acid gas, rising from the under portions that have undergone combustion, mixes with the atmospheric air that penetrates upwards, and makes it wholly unfit to support the combustion of the fuel with which it comes in contact. Even the hydrogen in a piece of dry pine wood, inserted in a mass of anthracite or coke in combustion, would flow through the red hot embers, without being inflamed. A piece of charcoal in the centre of a fire, if excluded from contact with air, will bear the fiercest heat without undergoing any change; but all the heat which it contains, while not in combustion, should be considered as so much wasted. Anthracite and coke, and some varieties of coal, with a small proportion of bitumen, are often from idleness or inattention put into the grate in large pieces; in that case scarcely any depth of fuel will be sufficient to intercept the cold air that flows through the wide spaces left throughout the mass. This kind of fuel should be burned in small pieces, and unless we can arrange its parts so as to allow a supply of air to all its surfaces, but which is impracticable, a greater depth of fuel than 4 or 5 inches should not be ignited. With that depth, the air which enters beneath may be effectually prevented from flowing through the fire, without decomposition; and it is evident that it will be supplied to the uppermost layer of fuel, much purer, and excite a more vivid combustion, than if the fuel was three times thicker. It need hardly be observed that, were the front bars replaced by a solid plate, as Mr. Bull recommends, the fuel chamber should be placed low, not more than 4 or 5 inches above the hearth, or in general no higher than would allow the ashes to be removed conveniently from beneath it; and the fender should not rise more than 2 inches above the hearth.

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* Experiments to determine the Comparative Value of Fuel p. 92.

The fuel chamber of the fireplaces for burning Newcastle coals, appears to have been generally constructed on a principle drawn from a similar analogy to that which seduced Mr. Bull, and is made much deeper than is proper. From 7 to 9 inches has been stated as a common dimension, but this is double nearly what it ought to be; from 3 to 4 inches would be better. With this thickness of fuel, little undecomposed air would escape it; and the hydrogen of the combustible would be supplied with that quantity of heat and air required for its inflammation, as it was evolved, instead of being distilled merely from deep masses, as now, and escaping as vapour into the chimney. To supply an open or other fire with fuel from the bottom, to prevent this loss, is, however, a kind of desideratum with smoke burners. But in these schemes the waste of effect is very apparent; a great part of the hydrogen of the fuel rises through the incandescent mass, without undergoing combustion.

The effect would be greater, were the fuel *sprinkled very thinly* on the top of the incandescent surface. When the coal contains much bitumen, it cakes when heated; and if added in large quantities, a black compact mass is formed on the top, from which the greater part of the inflammable matter exudes in the form of smoke, and radiation from that portion of the surface is also prevented.

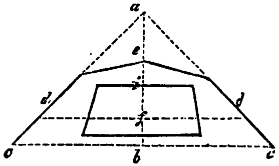
Where a greater surface is required, the fuel chamber should be extended horizontally, rather than vertically; for grates where common coal is burned in moderate sized pieces, the depth should be a constant dimension seldom exceeding 4 inches, the width and length only varying with the size of the apartment.

From the ever varying conditions of the problem, no general rules can be given for the proportion that an open fire should bear to the size of the apartment it is meant to warm. In eleven rooms varying from 1400 to 4360 cubic feet of space, the average surface of incandescent fuel, was 1 square inch to every 8·4 cubic feet of space. But as radiant heat does not warm the air it passes through, although a large room requires a large fire, this is supplied more with reference to the number of persons that may be congregated around it, than to the magnitude of the chamber. As much heat will be received by those standing at an open fire made on the snow in a field, as if it were blazing on the hearth of a baronial hall, or on the recessed hearth of a modern dining room.

The radiant heat being emitted in straight lines, the stream may be guided into a particular direction, by giving a certain form to the hot body. A globe radiates its heat in every direction: from a concave surface, the greater part of the rays will converge to a focus, and they will proceed at right angles to a plane surface. When the radiation therefore is to extend to all parts of the room, a circular or curved form should be given to the bars of the fuel chamber, and a straight bar with the ends enclosed should be avoided. One of the many advantages of the Staffordshire grate and its modifications, is the circular form of the radiating mass as well as its advanced position in the room. Where the fuel chamber is either wholly or partially closed; the enclosing substance should be a bad conductor of heat, such as fire-stone or Stourbridge bricks or fire clay.

A late smoke-doctor, in ignorance of Count Rumford's labours on this point, or perhaps in pursuit of distinction, ventured, as was his wonted manner, to give a rule of his own "to determine the position of the covings, so that they shall be best adapted for reflecting the heat of the flame into the room." "Make," he continues, "*b*, the middle of the front of the grate, and *b*, *c*, half the width, which is convenient for the opening; and make, *a*, *b*, perpendicular, and equal to, *b*; then join, *a*, *c*, and it is the direction in which the coving should be placed: a *greater* obliquity would be *still* more effective, because it would spread the rays more into the room, but is not so convenient in other respects. The back of the fire is usually straight, but unless the fire be small, it *is* an advantage to make the back in two parts, forming an obtuse angle at *e*; in this angle the smoke collects and ascends with less obstruction, than when it is dispersed over a flat surface." The reflecting back being

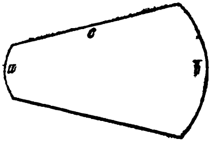
FIG. CXLVII.



placed at 3 inches from the back of the fire-chamber, is very effectual in admitting air to cool the column of smoke after it rises from the fire, and thus enabling it to be blown into the room by eddies, which is further aided by the angle for the smoke much enlarging the depth of the throat of the chimney; the broken back must reflect less of the heat of the flame into the room, than if it were formed straight according to the Count's instructions. On the whole the rule is a good one for spoiling a fireplace.

From a notion that the larger the surface of fuel exposed to the room a greater quantity of heat will be emitted, the space between the front bars is always made as wide as possible, and the bars as small; and the practice would be judicious, if the large exposed surface could be kept at a vivid degree of incandescence, but experience shows that the greater the surface, the more it is cooled by currents of air, and the more it intercepts the radiation from the interior. In a grate in which the space between the bars was diminished from 2½ inches to 1 inch, with a bar an inch in diameter, the exposed surface was encreased in steady brightness, the radiation was encreased, and the appearance was more cheerful. It was found superior to the wider spaced front, in burning the smaller sort of coal, and retaining the cinders better in the grate; and the bars always appeared freer from dust than those placed at greater intervals; and last, although not least in importance, the poker when wielded by an uncouth, barbarous hand, was not so destructive an implement to comfort as it usually is when the bars are placed wider. These bars were elliptical 1 inch in their vertical diameter, and half an inch in their horizontal diameter. Some old fashioned grates have semi-cylindric bars, with the flat side to the fire; and the form is good for bringing the fuel as near the front of the bar as possible, and not intercepting its radiation. The common circular bar is the next best, and is infinitely superior to that recommended by a late smoke-doctor, as shown in Fig. CXLVIII. The bar slopes towards the fire, *a*, which encreases the incandescent surface exposed to the chilling influence, but decreases the radiating surface towards the room, is adverse to the reflection of the heat that falls on its surface; and is found to be an "untidy bar," always covered with dust, which it seems formed to retain,—altogether it is a model of what is to be avoided.

FIG. CXLVIII.



The great object, says Count Rumford, in burning fuel in open grates, being to bring the radiant heat it produces into the room; and as a considerable portion of it is thrown on the surfaces within the hearth recess, it is of great importance to select a proper substance for the jambs. Bodies which absorb heat are heated by that absorption, and therefore what is adsorbed cannot be reflected; and as the jambs have to reflect the heat, they should be formed of substances which acquire the least heat when exposed to the direct rays of a clear fire. Fire stone and common bricks were recommended by this prince of smoke-doctors; and when bricks were used, to coat them with a fine plaster; and every part of the fireplace not exposed to be soiled by smoke, to be whitewashed and kept as clean as possible, as white reflects heat as well as light, and black, which reflects neither, should be avoided. The bars and bottom of the fuel chamber cannot be well made of any other material than iron; but as this and other metals when rough and unpolished, are known to get very hot when exposed to the rays of a fire, and to cool with great rapidity also, on this account they are the worst materials to employ about a fireplace of this description, as no current of hot air ever sets from any part of the hearth recess into the room, on the contrary almost the whole of the heat absorbed by the metal, is carried off by the current of air setting from the room into the chimney. Highly *polished* metallic surfaces are however excellent reflectors of radiant heat, and are unobjectionable, though expensive materials for covings.

It is to be noticed, moreover, that the Count delivered his excellent precepts as applicable to fireplaces in which the radiant heat alone was to be made effective, and to the most numerous class of cases where economy in the first cost of the apparatus had to be considered, as well as the economy of the heat. But prejudice and fashion in his own time were too strong for his philosophy; and when the price of all articles of iron was much greater than it is now, he had to raise his voice against the waste of heat, occasioned by its indiscriminate use in an unpolished state for the covings, and other parts of the hearth recess. In our thoughtless times, from the elegance with which it is fashioned for common fireplaces, and its cheapness, iron is now a common material for covings, even in cottages. The Count's opinion was unfavourable to the use of hot air stoves, not only on account of their expense, but from the air as before noticed, being small in quantity in consequence of its motion being impeded in meandering behind the covings and back; and being often over heated, it was said to be burnt and unwholesome when it entered the room.

From the position and form of the fire chamber the iron surfaces within the hearth recess are always kept at a high temperature. In a fireplace similar to that shown in Fig. CXLVI., with a fuel chamber 12 inches long, 8 inches wide, the hobs, covings, back, and ornaments had 5·7 square feet of surface, kept at an verage temperature of 160°, in a room having a cubic content of 1470 feet, or about 258 feet of space to one of surface. Now a stove having the same quantity of surface at the same temperature, would have kept this room at a comfortable heat in the coldest weather; that is, with a *small* portion only of the heat wasted in the hearth recess.

This enormous loss of effect from the injudicious use of iron, is, however, of most easy remedy. By a slight alteration of the fireplace, iron becomes the best, instead of the worst, material of which it can be composed: all that is required being to form the back and covings, that the air, which may be made to flow rapidly over them, shall he carried into the apartment instead of into the chimney. The method of doing this is exceedingly simple. It is merely to return to the Louvre grate as a model from which to form every fireplace having metallic covings, whether in a palace or in a cottage; but more especially in the latter, where economy of fuel, as well as the comfort of heat, is of vital importance to the inhabitant.

ESSAY XII.

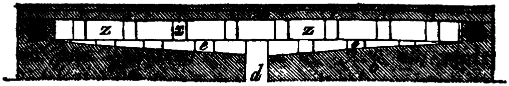
In Sir Robert K. Porter's description of the Persian method of heating rooms, he calls the apparatus a *kourcy*. Delavalle, who describes it with great minuteness, says the Persians call it a *tennor;* and it consists of a square or round hole two spans or a little more in depth, and shaped something like an Italian cask. In this hole is placed an iron vessel of the same size, filled with ignited charcoal or other inflammable substance, which is often among the common people the dried dung of graminivorous animals. A wooden top, like a small low table, is then placed over the hole, upon which is thrown a large cotton quilted coverlet, which hangs down on all sides to the floor; and over this is usually thrown another coverlet of silk, ornamented with embroidery. These coverings not only prevent the heat from rising to the ceiling, but diffuse it by exposing a larger heating surface to the air of the chamber. The Persians, who eat or converse there, and some who sleep in the apartment, lie down on the floor, above the carpet, and lean with their shoulders against the wall, on square cushions; and they sometimes employ the tennor as a seat, for it is usually constructed in a part equally distant from the wall on both sides. Those who are not very cold put their feet only under the covering, but those who are colder put their hands also, and sometimes creep under it altogether: and a gentle, penetrating, agreeable heat is thus diffused over the whole body. Those, however, who require less heat, let the coverlet hang down on their side to the floor, and enjoy without inconvenience the moderately heated air of the apartment.

When the fire in the tennor wants stirring or blowing up, it is performed by means of a small pipe, inserted through the iron vessel, which is made to rise above the floor as high as is thought necessary. When a person blows into this pipe at the upper end, it acts on the fire like a pair of bellows. At the return of warm weather, the stove-hole is closed up with a piece of stone, and the pipe rising above the floor is removed, so that when the floor is covered with a carpet, which it always is in this country, no appearance of fireplace is visible.

The Jesuit missionary, Grammont, gives a good account of the methods of heating rooms among the Chinese. A *kang*, says the father, is a kind of stove heated by a furnace, and varies in its construction. The ti-kang (of which the flue runs under the pavement); that for sitting on, which has been noticed in the Introductory Essay, is called kao-kang; and a third variety, formed in the wall, is named tong-kang.

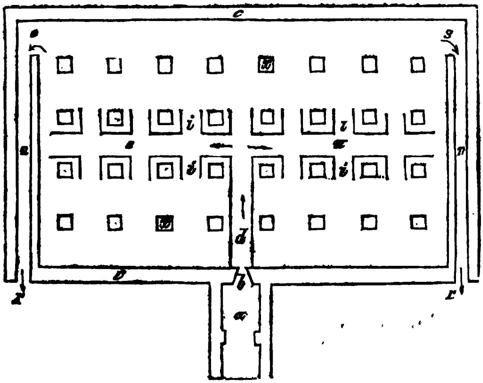
A horizontal section of the kao-kang is the subject of Fig. CXLIX.; and its vertical section of Fig. CL., taken on the length of the kang.

FIG. CXLIX.



The furnace, or fireplace, *a*, is placed considerably under the level of the floor, and is shaped like a cone, somewhat arched. The poor who are glad to make the most of their fuel, place the furnace in the room that is heated, the middling sort in an adjoining room; but the rich form it on the outside, commonly under a north wall. An opening, *b*, is made through the wall, *c*, into a heating flue, *d*, that is carefully built of bricks, well cemented with mortar. This flue rises with a quick ascent from the furnace, and at the centre of the kang, another flue, *e u*, branches off at right angles, to the right and left. This flue has openings, *i*, *i*, at each side, for the admission of the heated vapour coming from the furnace, into the space, under the top of the kang on which the family sit. The floor of this space, *a*, *a*, is made of well rammed clay, or bricks, placed edgeways, or large paving tiles. On this floor, or paving, small square piers, *x*, about a foot high, are firmly set, at such a distance from each other as to support the four corners of each of the large tiles, *m*, that are placed on them, to form the roof of the kang. The depth of this space, varies from 12 inches to 18

FIG. CL.

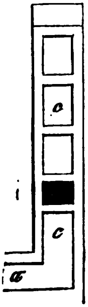


inches. The smoke, after it has spread into the space, under the roof, *m*, then enters the flue, *n*, at the points, *o*, *s*, and is emitted at the apertures, *r*, *r*, which, among the poor in towns where fuel is scarce and dear, open into the room—but in the country, and in gentlemen's houses, they open to the outside.

A fire being lighted in the furnace, the smoke rises into the heating flue, *d*, and then flowing into the flue, *e*, it rises through the lateral openings, *i*, *i*, into the space under the pavement, and heats the floor, *m*, of the kang.

The ti-kang, or floor-kang, is built like the kao-kang, but it has only one heating flue, which rises from the furnace under the pavement which is hollow, to the further end of the apartment to be heated. Small lateral apertures are made in this flue, as in the kao-kang, to allow the smoke to spread from the flue into the space under the floor.

FIG. CLI.



The tong-kang, or kang built in the wall, differs from the ti-kang only in its perpendicular position. In this the heating flue is carried along the floor, with openings from it at which the smoke ascends into the spaces of a hollow wall, and sometimes the heating flue is carried backward and forward as it rises along the length of the wall. A good notion of this variety will be had from the tong-kang by which Sir William Chambers heated the orangery at Kew Palace in 1761. He there also, in imitation of a Chinese practice, introduced heated air into the house through an *air-pipe* or flue, in contact with the heating flues. In the Fig. CLI. the flue from the furnace is shown at *a*, the kang flues at *c*, and the hot air flue at *e*.[*]

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[*] Plans and Elevations of the Gardens and Buildings at Kew, p. 3.

The bricks forming the pavement in the ti-kang are of a large size to diminish the number of joints. Those in the royal apartments are 2 feet square and 4 inches thick, and cost, says Grammont, near 100 crowns a piece. They are of a grey colour, owing to the manner in which they have been baked; and when coloured and glazed they are most beautiful, and appear as delicate as marble. In the palace and in great houses, the floor of the room over the kang is laid with two courses of large bricks to prevent the rise of the vapour, and moderate the heat. The mortar used in building the flues and bedding the tiles, is composed of one part of white or quick lime and one part of black lime. The black lime is found, says Grammont, at the entrance of coal-pits, and seems to be no other than coals dissolved by rain. The mortar mixture is excellent, and nearly resembles cement; and being proof against rain and sun, also is used to cover whatever is exposed to the weather. As soon as the kang is finished, a fire is made to dry it *quickly*, and all the little holes at which vapour may ooze are carefully stopped by a mortar tempered with a kind of varnish called tong-yeou. The wealthy paint over the floor when heated with the varnish only, in order that the bricks when not glazed may imbibe it more readily.

All kinds of fuel are burned in these kangs; but in the palace and best houses wood only is used, or a kind of coal that burns like tinder, and neither smokes nor smells. The general fuel is pit-coal, and charcoal, and the poor in the country burn furze, straw, and cow-dung; and Mr. Ellis says, the dried broad leaf of the nelumbium also,* which is cultivated extensively on the banks of rivers for that purpose. They also burn a prepared fuel composed of coals pounded to the size of coarse gravel, which, added to one third or an equal quantity of yellow clay, and kneaded into the form of bricks, give a greater and more pleasant heat, besides being much cheaper than coal or charcoal.

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* Account of Embassy, p. 45.

The furnace is made exceedingly small, when compared with what would be our practice in a similar case, and five or six hours are required to heat the pavement of the ti-kang; but when thoroughly heated, Grammont observes, it takes but little fuel to keep it warm. At Pekin the thermometer is almost all the winter between 11° or 2° Fah.; and although all the rooms are on the ground floor, and have nothing but paper windows, the heat from the kang is sufficient to keep their temperature as high as 48° or 50° Fah. with very little fire. The heat in the emperor's apartments, owing to the double strata of paving tiles, seldom rises higher than to 41° or 44° Fah., and the warmth is very gentle and penetrating.

In order to correct the noxious effect of the vapours exuding from the joints of a kang, always heated, bowls of water are kept in the rooms and constantly renewed, and gold fishes are preserved in them as an ornament and for amusement. The emperor's apartments, and those of persons of rank, are decorated with flowers in pots, and orange trees, which the philosophers pretend is the best way to absorb noxious vapours and purify the air. The poor enclose a vessel of copper or iron within the brick-work of the furnace, which, besides supplying them with hot water for tea, is allowed to evaporate during the night, to moisten and purify the air in the room, into which the vapours of the kang are admitted.*

In the plan of the kao-kang, the smoke-flue is shown terminating in the apartment, as practised to economize heat among the poorer Chinese, who move about in their houses scantily clothed. The construction of their houses constrains the better classes to live in apartments comparatively cold, and form a comfortable portable climate by an abundance of warm clothing. Their rooms are generally very spacious and lighted by very large windows, usually filled with fine silk or cotton stretched on frames, or of a thick paper made in Corea; occasionally, in some places, with glass or polished oyster shells. They are usually left open when they look towards the south, especially in rooms for the reception of company.

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* Philosophical Transactions, vol. lxi. part ii. p. 51.

At entertainments, the two principal persons are seated on the kang, and the other guests sit nearest to it, according to their rank; but however comfortable may be its heat to those on or near it, it is not well calculated to promote the enjoyment of all the guests in a large party. When these are incommoded by the cold, the host accommodates his company with wide-sleeved spencers, lined with costly furs,* with which he stores his wardrobe against the cold weather, as an Englishman does his cellar with wood and coals. From the large openings in their houses, the better classes of Southern Chinese may be said almost to live entirely in the open air, even in their sharp winter, by the use of warm clothing. Mr. Abel says the cottages were of mud, without windows, and exposed to the air by a thousand apertures.† Mr. Ellis observed, that the Chinese did not seem to understand how to combine the admission of light with the exclusion of air. You may enjoy warmth and darkness, but light must be shut out;‡ but this follows from the great size of the good radiating paper or silk surface of their windows, and the small size of the kang furnace.

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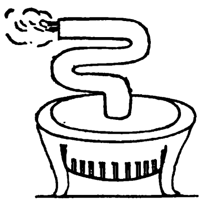
* Davis. The Chinese, p. 158.
† Narrative of Journey, p. 77.
‡ Journal of Embassy, p. 78.

Their kitchens are generally without chimneys, and the smoke escapes through a hole in the roof; and the plaster of the ceiling of an old kitchen is so much valued as manure, says Mr. Davis, that they will sometimes put new plaster on the roof for the sake of the old. The kangs of the better houses have chimneys carried above the roof; and at an inland town, Mr. Ellis observed, that houses two stories high with chimneys were common. Brasiers filled with lighted charcoal, are sometimes introduced into the kang, and withdrawn when the desired heat has been produced. The same implement is used as a temporary expedient to heat rooms. Open fires burning on a hearth are also seen but rarely in farmhouses.

In European countries, covered brasiers or enclosed fireplaces are the most general distributors of heat. Dr. Clark calls them Dacian, and M. Morveau Russian stoves. Among us they are known as German stoves, of which the Dutch and Swedish and other combinations are varieties.

FIG. CLII.



A covered brasier, with the addition of a pipe to carry off the carbonic vapour, is the simplest form of the apparatus; and if the pipe were bent as in the figure, a larger heating surface would be obtained, and the smoke retained longer in the apartment, while the combustion of the fuel would be retarded.

The Dutch stove is the next step. Its heating surface is increased by a space left above the fuel, as in

Fig. CLIII., but not separated from it, and the smoke is emitted by a pipe. This, which is the simplest form, is also the most useful, and that generally adopted in heating on the large scale.

Where it is desired to obtain a greater proportion of heat from the smoke, it is made to pass, in the following diagrams given by Keslar,* into a second chamber. as in Fig. CLIV., or into a third chamber, as in Fig. CLV.

FIG. CLIII.

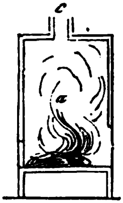


FIG. CLIV.

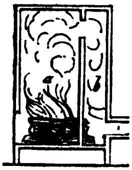


FIG. CLV.

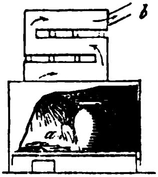


FIG. CLVI.

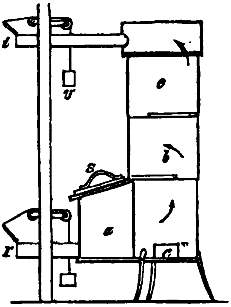


Fig. CLVI. is an example from the same collection of a stove formed of wrought iron, and is given more especially to show the ancient method of supplying fuel, and regulating the draught and exit of the smoke: *a*, the fuel chamber; *c*, door of ash-pit, opened only to remove the ashes, and above which is the grating on which the fuel is laid; *s*, door or lid of fireplace, always kept closed, except when introducing wood. This will be recognised as the type of the modern stoves, which contain a magazine of fuel. The hot vapour passes into the circular chamber, *b*, thence into *c*, and makes its exit at the mouth of the pipe, *i*, which is furnished with a valve or smoke damper, *i*, retained in the situation it may be placed in by the counterpoise, *v*. The fuel chamber is made capacious, and filled with wood at once; but the area of the pipe, through which the air rises into the ash-pit, is very small, and the quantity of air admitted is further regulated by the valve at the extremity of the air-pipe; and this ancient stove-doctor had a notion, that the longer the pipe through which the air flowed, the steadier and better was the draught into the fireplace. Fig. CLVII. is an example of a stove, built with tiles, and described by Keslar: *o*, door of ash-pit, always closed, into which the air is admitted by the pipe, *c*, under the fuel laid on the bars of the fire-chamber, *b*, which is supplied with fuel from above, by opening the lid, *a*; and the smoke rises in a zigzag fashion through five horizontal chambers, and escapes at the pipe, *i*. A hollow space, it will be seen, is left between each circulating chamber, with the intention of increasing the surface exposed to the apartment, as in Fig. CLVII.

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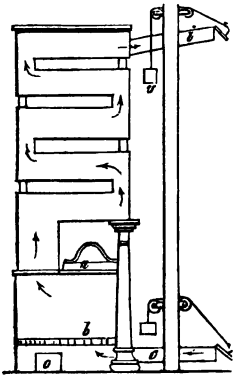
* Epargne Bois, p. 7.

FIG. CLVII.



To M. Montalambert, says M. Morveau, is due the first introduction into France of stoves on the Russian construction. He called them cheminées poëles, and about 1767 several were erected at Paris; and even some Russian workmen were brought thither in order to have every advantage that the most perfect construction afforded.*

Berthollet, in a report to the French Government, distinguished the Russian or German stove from the Swedish, by the smoke in the former, after it rises from the fuel, *receding* to a distance from the fireplace into the flue, so that it was was merely cooled by contact with the walls of the circulating chambers, and its heat by this means retained in the apartment, which would otherwise have escaped combined with the vapour. On the contrary, in the Swedish stove the circumvolutions of the smoke were exposed to a vivid heat, and the disposition of the flues was most favourable for the fuliginous vapour undergoing a second combustion in the circulating channels.

In the following diagrams for the convolutions of the flues given by Leupold,† the smoke comes again into contact with a part of the highly heated surface of the fuel chamber, and according to M. Morveau's definition would form a Swedish stove, and spaces might be left between each division to increase the heating surface.

FIG. CLVIII.

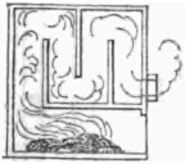
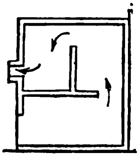


FIG. CLIX.



About 1767, Count Cronstedt was appointed by the Swedish Government to publish an account of the best manner of constructing stoves to economize wood; and Baron Wrede communicated to him the experiments on stoves, which for several years had engaged his attention. The joint labours of these distinguished persons were placed in the hands of M. Palmstedt, an architect at Stockholm, who was engaged to prepare the drawings from which engravings were made, and published along with some observations by Baron Carl Sparre, in 1775.*

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* Rep. of Arts, vol. ii. p. 37.

† Theatrum Machinarum, vol. iv. p. 186.

Some of the stoves in this collection, says M. Morveau, have four, five, and even nine flues for the circulation of the smoke; some are contrived to receive one or more boilers, and others to act as ovens; and all of them produce a great saving of heat, for the quantity of fuel which will last sixty-three days in a stove, will be consumed in twenty-three in an open fire, and with less effect.

One of these stoves adapted for burning wood, is shown in plan, Fig. CLX.; in a longitudinal vertical section, Fig. CLXI.; and in a transverse vertical section, Fig. CLXII.: *a*, the fuel chamber, *b*, *c*, *d*,

FIG. CLX.

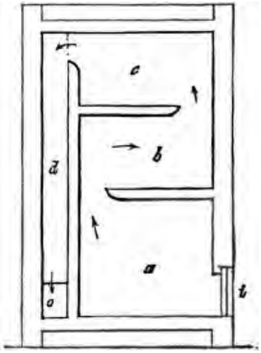


FIG. CLXI.

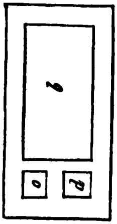
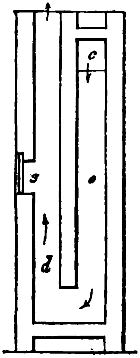


FIG. CLXII.



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* Repert. of Pat. Inv. vol. ii. p. 89.

the chambers or flues of circulation: the furnace door has a valve, *i*, to admit air to supply the fire, and there is a damper or smoke valve fixed at the junction of the last circulating flue with the pipe that conveys the smoke into the chimney. The length of the fuel chamber is 42 inches, its width 21 inches, its height 36 inches, and the height of the chambers, *b*, *c*, is 18 inches; the flues, *d*, *o*, are 7 inches on the side.

The billets are sawn of equal length, and as many of them put in at once as the fireplace will hold; the wood is lighted, the fire door shut, and the air valve in it opened; at the same time the stopper that closes the small aperture, *s*, into the flue, *p*, is taken out, and a few bits of paper are burned in the flue to produce an upward current. The stopper is then quickly replaced, and a sufficient rarefaction having been made to establish a draught from the fireplace, the circulation of the smoke in the channels will then go on uninterruptedly in the direction shown by the arrows in the figure—rising from the fuel chamber, *a*, into the chambers of circulation, *b*, *c*, *d*, successively, then descending by the flue, *o*, and finally ascending by the flue, *d*, into the chimney. When the wood is sufficiently charred, the air valve in the fire door, *i*, and the damper are closed, and all the heat in the fuel and body of the stove is retained in the room, and warms it long after the combustion of the fuel has been suspended.

In the Swedish stove, as altered by M. Morveau, the defects of the type are greatly aggravated. Two horizontal sections of this apparatus are shown in Fig. CLXIII., and another in Fig. CLXIV., and a vertical section in Fig. CLXV.: *a*, the fuel chamber, enclosed on two of its sides by parallel iron plates with a space, *c*, between them, formed like a "case of meanders" described in Cardinal Polignac's chimney. The fire chamber, *a*, is 9 inches wide, 20 inches long, 14 inches high. The air-chamber, *n*, is 8 inches high, 16 inches wide, and 18 inches long, which is the inside width of the stove, its length inside being 29 inches. The width of the flues, *i*, *i*, is 6 inches, their length 18 inches. The height of the horizontal flue connecting at *v*, 9 inches. The height of the stove from the hearth to the underside of its roof is 60 inches. The air-pipes, *s*, *s*, 4 inches in diameter. The space, *c*, for the warm air, was 3½ inches. The external air, or the air of the room, is admitted into the lower division of the meanders, and rising through one into the other, flows into the air-chamber, *n*, where it receives an additional supply of heat before it is emitted into the room by the "bouches de chaleur," or warm air-pipes, *s*, *s*.

FIG. CLXIII.

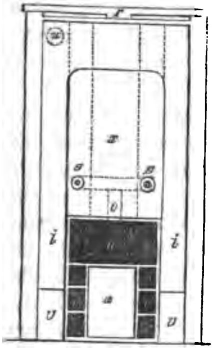


FIG. CLXIV.

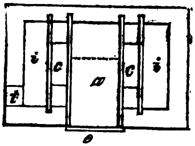
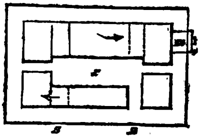


FIG. CLXV.



From the position of the parallel plates forming the hot air channels, their surface must always be nearly red hot, as well as the bottom of the air chamber, *d*; and the air which passes through them must be decomposed or rendered unfit for the process of inhalation. The arrangement of the circulating flues is, however, neat, and where compactness is desirable it would be a good model; and also where it was required to combine a ventilating with a heating stove, the side iron air-plates, without the meanders, would make it a meritorious apparatus.

To have the proper effect of stoves of every kind, it is an essential condition that they stand *detached* from the wall; and for the same reason, the more the heating flues are insulated from each other, the greater effect will be produced by an apparatus having the same general dimensions. In this view the Russian stove, shown in the previous figures, is somewhat superior to the Swedish, especially on M. Morveau's model, in which the flues are grouped more compactly.

M. Morveau recommends a vase kept filled with water, to be placed on the top of his stove, to impart by evaporation the necessary moisture to the air of the room; and the contrivance has been from time immemorial in general use in countries where enclosed stoves are adopted.

It is evident, although the smoke in its circumvolutions is brought in contact with the heated side formed of a thick tile of the fuel chamber, that no second combustion of the vapour, or, as it is technically called, burning the smoke, can take place; and that the only effect produced by exposing the circumvolutions to a vivid heat is to impart a higher temperature to the smoke at its entrance to the chimney flue, than it has in the upper circulating chamber, and by this means to give a greater velocity to the air entering the fireplace. But then all the heat imparted to the smoke in the last flue escapes up the chimney, without producing any effect in warming the air of the room, which is against M. Morveau's excellent maxim that the only useful heat is that sent into or retained in the apartment; and as it must be considered as so much heat lost, it becomes a positive defect from which the Russian stove is free. Both fireplaces being the same in every respect, and also the quantity of fuel, the air would enter the fireplace of a Russian stove with a velocity equal to that in the Swedish stove, and the smoke escape at a lower temperature; from the arrangement of the flues, the retardation of the current is less in the former than in the latter apparatus; and this increased retardation is a measure of fuel wasted.

Neither is the greater heat supposed to be given to the surface of the Swedish stove by this brisker circulation of the smoke at all an advantage; for it has been laid down as a maxim, and applicable to heating stoves on every construction, that the more vivid or perfect the combustion in the fireplace, and the *cooler* the surface of the stove, or the nearer it is in temperature to the air of the room, the more perfect and salubrious will be the heating apparatus. And this desirable result is only to be attained by exposing the greatest quantity of heating or absorbing surface to the action of the least quantity of fuel. In most modern stoves this condition is almost reversed.

In the North of Europe there is a bias in favour of descending flues, from being thought more effective in inverting the internal arrangement of the column of smoke, and consequently the circumvolutions of the flues in M. Morveau's stove, but without the air-pipes and air-chamber over them, is much commended and used. In the following figures, the circulating flues are supposed to be formed of cast or wrought iron, and to be *insulated* from each other and from the fire-chamber, so as to expose the greatest possible extent of heated surface to the contact of the air. Fig. CLXVI. is a horizontal section taken through the fireplace. Fig. CLXVII. a horizontal section through the upper horizontal flues. Fig. CLXVIII. a vertical section through two flues, *e*, *h*, on the length of the stove. Fig. CLXIX. a vertical section on the width; and Fig. CLXX. also a vertical section through the flues, *f*, *e*. The small arrows show the course of the smoke. The fire-

FIG. CLXVI.

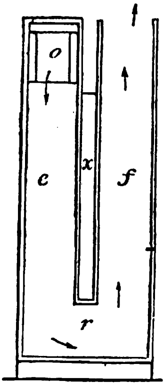


FIG. CLXVII.

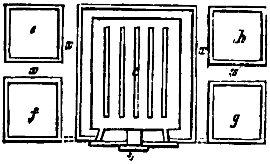
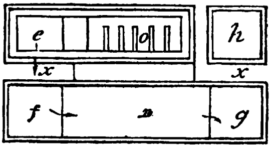


FIG. CLXVIII.



chamber, *c*, is 8 inches square, and 8 inches deep from the upper side of the fuel bars to the sill of the fire-

FIG. CLXIX.

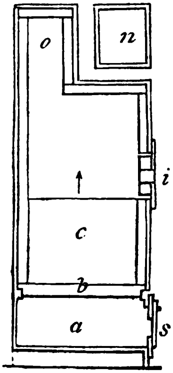
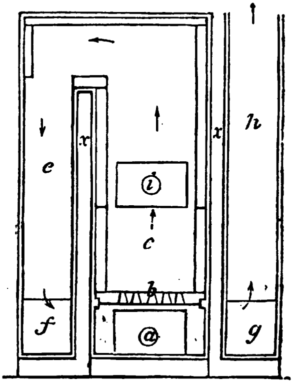


FIG. CLXX.



door, which is 4 inches high and 7 inches wide, with a valve, *i*, for admitting air when necessary, to the surface of the fuel. The fire-chamber from the fuel grate to the roof is 19 inches high, and lined on its sides and roof with fire-tiles 1½ inch thick, and the fire-door is also lined with brick. The flue, *o*, that rises from the fire-chamber, is also lined with fire-brick to its junction with the descending flue, *e*. All the circulating flues are insulated about 1½ inch from the fire-chamber, and from each other, by spaces, *x*, so as to admit the air to all their surfaces. The ash-pit, *a*, is 4½ inches deep, and raised an inch above the floor. Its door, 4 inches high, by 7 inches long, has an air-valve, *s*. In this, as in all other stoves and furnaces, much of the effect depends on an accurate and close fitting of these doors and valves; small openings with stoppers made at the bottom of the flues, *g*, *f*, for the purpose of clearing the flue from soot, are to be reluted and made air-tight as often as they are opened.

The operation of the stove is the same as that of M. Morveau's. The hot vapour rises from the fire-chamber into the horizontal flue, *o*, descends through *e* into *r*, thence rises through *f* into the horizontal flue, *n*, and descends through *g*, and ascends in *h*, which is connected with the chimney flue. In stoves with descending flues, some artifice is necessary to create a draught, and in these stoves there is generally a small door for this purpose (as in Fig. CLXV.) in one of the flues, in which to burn a small quantity of some inflammable substance, to commence a circulation; but the same effect may be more conveniently produced by forming a connection between the upper part of the fire-chamber, and the smoke flue, by a pipe with a valve or damper, inserted into the last ascending flue. At lighting the fire, the valve is opened, and the smoke rises through the pipe into the chimney. When the draught is established, the valve is shut, and the smoke descends in the flue, and the circulation thus begun continues.

It is obvious that the stove shown in the figures may be surrounded with a casing, and have the external air admitted into the interior. Where this is practised, the casing should not be more than 1½ inch distant from the outer surface of the circulating flues. A stove of these dimensions would expose a heating surface of 36 feet square.

The Swedish instructions recommend, when using bricks or square tiles, to lay them on their broadest side, and to choose them as thin as possible for the interior partitions. The exterior is very frequently cased with glazed tiles. The stove is generally from five to ten feet in height, and from three to six feet wide, for rooms of ordinary capacity. The great size follows as a matter of course from the material they are built of, and the loss which it produces of the heating effect of the fuel.

The *intention* of enclosing the smoke in channels is to abstract its heat by bringing it in contact with the material of which they are composed; and the heat may be considered a current which, if not *absorbed*, passes up the chimney and produces no effect. Vitreous substances, marble, freestone, porcelain, and bricks, absorb a great part of the heat which falls on them, and their surfaces quickly become very hot, but the heat, which they imbibe with rapidity, they transmit very slowly throughout their mass; a marble or brick tile, or a rod of glass, may be held in the hand at one end, while it is red-hot at the other. A piece of copper will allow 90 parts of heat to pass through it in the same time that 37·4 parts will pass through iron; 18 through lead, while 2·3 parts only will pass through marble, 1·2 through porcelain, and 1·1 through brick earth. A fire, therefore, encased in copper, will heat a room twice as fast as if its top and sides were enclosed with iron; and an iron stove will emit heat thirty times faster than one made of porcelain or tiles, supposing the latter materials could be used as thin as the former; but as they must be several times thicker, their comparative effect would be farther diminished. In the same substance, it is obvious that heat will be conducted more rapidly through a thin than a thick plate: an iron cockle, ⅛ inch thick, will transmit 22 parts of heat in the time that one, ⅜ inch thick, will conduct 16·6 parts, and an inch plate 10 parts. By increasing the thickness of metal, the same effect may be produced as by using marble or porcelain.

Very thick metallic plates, porcelain, fire-stone, or tiles, are improper materials of which to form a stove, where economy of heat is desirable. The inner surfaces of the flue get very hot; and they cannot reduce the temperature of the vapour under their own. The casing of a stove should not only have a good receptive surface to imbibe all the heat thrown upon it, but it should conduct that heat rapidly through its substance. Thin plates of unpolished copper or iron, which unite these two properties in a considerable degree, are the best substances of which to form an air-heating apparatus. Iron stoves are very common in Germany; but according to Dr. Buxton, in Russia, where we should least expect to find them, stoves cased with earthenware or tiles are general, because these latter materials imbibe the heat from the smoke, and form a sort of magazine of caloric, which is given out to the room when the fire is extinguished. In some cases it may be desirable and convenient to have a low heat given out during some period to the room,—but procured in this manner, there is a great loss of effect. With tile or brick flues, it is impracticable to abstract a moderate portion of the whole heat from the smoke, for, as has been observed, its accumulation in the substance of the flue, or casing, enables the vapour to rise at a high temperature into the chimney.

In the construction of stoves of all kinds, the following points are always to be kept in view: "to maintain in the fireplace the high temperature necessary for the perfect combustion of the fuel, by enclosing it with substances which are good retainers of heat, such as fire-stone or bricks; to have the means of regulating the quantity of air admitted to the fuel by valves in the doors, which enclose the ash-pit and fire-chamber, and by accurate fitting of the doors and valves themselves;—much of the ease of managing the heat of a stove, and comfort in its use, depends on attention to this last circumstance: thirdly,—to bring all the gaseous products of the combustion, as they are emitted from the fuel, in contact with the largest possible area of conducting surface, so as to preserve it at an equal temperature; and lastly, to make the smoke enter the chimney with the smallest velocity, or lowest temperature that is practically consistent with the first condition. In no case should this temperature exceed 150°, nor should the metallic surface ever be raised higher than 100°, nor the stream of air issuing from it exceed 70°. There is no mechanical impediment to insure this result at all times, as in every case the combustion can be regulated by the admission of air; and if circumstances prevent the heating surface being enlarged to the proper proportion, the fire may be reduced so as to produce no more heat than can be carried off by the radiation and conduction of the given surface."

In the Russian and Swedish stoves, ascending and descending flues are considered necessary to abstract the greatest amount of heat from the smoke. In the common Dutch stove, the smoke is conducted from the fire-chamber into horizontal or vertical pipes, generally formed with bends or elbows. To determine what effect these ascending and descending flues and elbows have in arresting the heat combined with the smoke flowing through the pipes, Mr. Bull made the following experiments. A room which was 8 feet in length, in width, and height, was formed within another room, that was 14 feet long, 11 feet wide, and 9½ feet high, that could be closed from the atmosphere, but the air circulated in the space between the walls and ceiling of the two rooms. This inner room was successively heated by means of an open fireplace for burning wood, an open parlour grate for burning stone-coal, a cast iron ten-plate stove, and a sheet iron cylinder stove; and the quantity of fuel that was consumed by each apparatus to keep the room at the same temperature for the same time, was carefully noted;—the results are given in the following table:—

DESCRIPTION OF APPARATUS.	Time the room was maintained at the same temperature by the combustion of equal weights of fuel, compared with No. 9.	Weight of fuel required by each apparatus to maintain the room at the same temperature and for the same time, compared with No. 9.
1. Chimney fireplace of ordinary construction for burning wood	10	1000
2. Open parlour grate of ordinary construction for burning anthracite coal	18	555
3. Open Franklin stove, with one elbow joint and 5 feet of six-inch pipe placed vertically, the fireplace being closed with a fire-board	37	270
4. Cast iron ten-plate stove with one elbow joint and 5 feet of		

Description of Apparatus.	Time the room was maintained at the same temperature in the combustion of equal weights of fuel, compared with No. 9.	Weight of fuel required by each apparatus to maintain the room at the same temperature and for the same time, compared with No. 9.
four-inch pipe placed horizontally entering the fire-board . .	45	222
5. Sheet iron cylinder stove, the interior surface coated with clay lute with one elbow joint and 5 feet of two-inch pipe placed horizontally, entering the fire-board	67	149
6. Sheet iron cylinder stove, as before described, with 13½ feet of two-inch pipe in which there were three elbow joints; the whole placed as follows—3½ feet horizontally, 5 feet vertically for an ascending current, and 5 feet vertically for a descending current, entering the fireboard . .	78	128
7. Sheet iron cylinder stove, as before described, with 13½ feet of two-inch pipe, in which there were 3 elbow joints placed as follows—9 inches vertically, 12¾ feet horizontally, entering the fire-board	82	122
8. Sheet iron cylinder stove, as before described, with 9 elbow joints, measuring 13½ feet of two-inch pipe, entering the fire-board	95	105
9. Sheet iron cylinder stove, as before described, with 42 feet of two-inch pipe, which appear to have had 17 elbow joints .. .	100	100

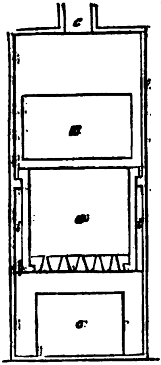
Assuming the quantity of heat developed by using the apparatus No. 9, to be 100, then, if the time occupied in any other experiment be deducted from 100, the remainder shows the positive loss sustained in every 100 parts of heat by using that particular apparatus. In No. 1, for instance, only 10 out of 100 parts of heat were given to the room, and consequently there was a loss of 90 per cent. by using that apparatus; and from the second column it is seen that 100 lbs. of fuel are required to heat the same room by an open fire, and 10 lbs. only by a sheet iron stove having 17 elbow joints.

The experiments, 6, 7, and 8, were made with the same stove to determine the effect of the different constructions and positions of pipes of the same length, which in all other respects were similar, and from these it is apparent that the same length of pipe is much more efficacious in imparting heat to a room when it has elbows, than when it is straight; and, as the length of pipe producing a descending current was nearly equal in the experiments to that producing a horizontal current, the great advantage which has been supposed to be derived from the descending current does not appear to exist, although it may be somewhat more efficacious than the same length and position of pipe producing an ascending current. Experiment 7 shows that a horizontal pipe, with the same number of elbows, is more efficacious in imparting heat than when placed vertically for an ascending and descending current. The cause of the increased effect, Mr. Bull observes, seems to arise from the shape of the pipe forcing the heated air to make abrupt turns, in doing which it impinges against the elbows with sufficient force to invert its internal arrangement, by which a new stratum of hot air from the interior of the current is brought more frequently in contact with the sides of the pipe, and particularly with the lower half of the horizontal pipe, which, from various causes, gives out very little heat to the room without the aid of elbow joints. The two last experiments show also, that in ordinary circumstances the advantage gained by increasing the length of pipe and number of joints has a limit very far short of that which is found to be necessary to impart all, or the greatest part, of the heat generated to the air of the room. Only 5 parts in 100 were lost by using 13½ feet of pipe, consisting of 9 elbow joints; whereas, 8 additional elbow joints, and 16½ feet additional of straight pipe, in all 28½ feet of pipe, were required to save these 5 parts, and prevent their flowing into the chimney.

The great advantage gained by lessening the current of air from the room into the chimney, is apparent from Experiment 2. In this the increased effect is not produced so much from the greater quantity of heat which enters the room, when compared with Experiment 1, but from the diminished quantity of cold air that requires to be admitted to supply the place of that which is heated and constantly flowing up the chimney in the first experiment. The gain of heating effect by using the pipe of smaller diameter arises partly from the retardation of the current, and partly from the small pipe exposing a greater surface to the air with the same quantity of smoke than a pipe of a larger diameter; and whether the velocity of the current is diminished by the construction, position, or length of the pipe, or its volume diminished by reducing the diameter, in every case the same effect is produced.

The common form of the Dutch stove, as constructed on the small scale, is shown in section, Fig. CLXXI. The fire-chamber, *a*, is formed by a cast iron cylinder, 6 inches in diameter, with a ledge at its lower end, on which the cast iron grating is supported,—this is often fixed at the distance of an

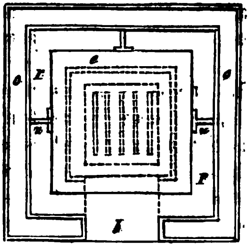
FIG. CLXXI.



inch or more from the outside case of the stove. The ash-pit has a door, *o*, furnished with an air-valve; the smoke from the fire-chamber rises into the pipe, *c*, which is generally continued, where economy of heat is studied, by a pipe with elbow joints into the chimney flue. No heating stove apparatus is more simple and easily formed than this, and by proper care to make the ash-pit and fire-doors close exactly, and exclude all air from the interior except that admitted at the air-valve, and placing a damper in the flue pipe, the effect of the most complex stoves may be produced without their many disadvantages.

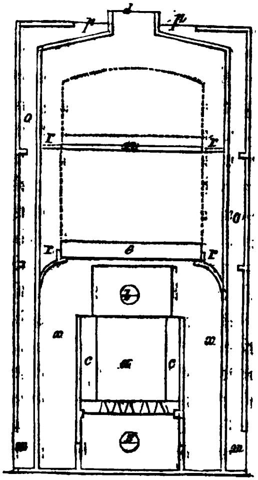
The general defect of this apparatus arises from the mass of fuel being out of all proportion to the metallic casing, which is consequently kept at a very high temperature, and is often red-hot. A fire-chamber 7 inches in diameter and 7 inches deep is usually enclosed in a casing containing 5½ square feet of surface. The same fireplace would be sufficient for 20 or 30 feet of surface;—and even with that capacity the top of the stove exposed to the upper surface of the fuel, unless protected, will generally be overheated.

FIG. CLXXII.



The stove shown in plan, Fig. CLXXII., and section, Fig. CLXXIII., is on the same plan as the preceding, with some additions which obviate several objections to the Dutch stove, without destroying its simplicity. The fire-chamber, *a*, 8 inches on each side and 8 inches deep, is enclosed by four fire-tiles, c, c, 1 inch thick, which are placed in a cast iron case, ⅜ inch thick, cast with a ledge to support the fuel grating, and projecting 3½ inches downwards into the ash-pit, terminates in four short standards or feet placed on the sole of the stove. A space, a, of 4½ inches, is left all round between this iron casing and the inner casing of the stove. At the distance of 5 inches above the upper edge of the tiles of the fuel-chamber, a fire-tile, e, 1½ inch thick and 15½ inches square, is fixed on cleats or brackets, so as to leave a space, r, about 1½ inch all round between it and the inner surface of the casing for the hot vapour from the fuel to rise upward. A plate of iron, n, or a tile, is fixed about 8 inches above the tile, e, also leaving a space, r, about 1½ inch between its edge and the casing; the roof of the stove, about 8 inches above the plate, terminates in the smoke-pipe, d; the fire-door and its valve is shown at b, and the ash-pit door and air-valve at s, the under edge of this valve being half an inch above the under edge of the iron casing of the smoke-chamber. The stove is enclosed in a plate iron casing so as to leave a space, o, of 1½ inch round it. This outer casing is open at the bottom, m m, and at the top, p p, and has two fillets projecting about half an inch from its surface; no valve of any kind is attached to

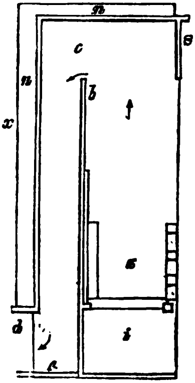
FIG. CLXXIII.



this outward casing, and the air has free ingress and egress to the space, *o*, that it encloses. All the parts are accurately fitted, and no air enters the stove, except through the valves at *s* and *b*. The heating surface was 20½ square feet, and the depth of coke in the fire-chamber was generally about 5 inches; and this was found sufficient for a room containing nearly 5600 cubic feet of space. When there is fire, the hot vapour from the fuel, being prevented from rising in a stream upwards by the tile, *c*, spreads along its under surface, and ascends all round the edge of the tile through the narrow space, *r*, which brings the smoke into contact with a large surface of the iron casing, and this contact is prolonged until it reaches the roof by flowing through the narrow space between the upper tile and the casing; the whole surface of the stove, thus kept in contact with the smoke, is equably heated, and the air which rises freely in the space, *o*, being brought rapidly in contact with this hot surface, is genially warmed and emitted, at *p*, into the room.

The hall stove, a variety of the Pennsylvanian fireplace, combines much of the cheerfulness of an open fire with many of the advantages of a stove. Fig. CLXXIV. is a transverse vertical section; *i*, ash-pit; *a*, fire-chamber, 7 inches deep, 7 inches wide, and 12 inches long, with an opening of 14 inches between the upper grate bar and the mantel-plate, *s*, which is 5 inches deep; *c*, the throat, 3 inches deep, and the descending flue, 4 inches wide, leading into the horizontal flue, *d*, that conveys the smoke to the chimney, and in which in

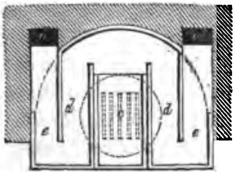
FIG. CLXXIV.



all cases there should be placed a valve or damper. The stove is set in the hearth recess, and insulated by leaving a space, *n*, 2 inches wide all round it. This, in many cases, when compared with a common fireplace, is an economical and pleasant apparatus.

The stove exhibited by Daslesme in 1680, was imitated by Dr. Franklin, who had one, says Mr. Danforth, in his bedroom. "The front of the chimney was completely manteled or stopped, but there was a canal about 3 inches square in the hearth, running under the middle of the mantel, and opening into the chimney. On the outside, this canal was covered, except a hole about 3 inches diameter, over which was set a stone cylinder of about a foot in diameter, and two feet high, having a hole through its whole length answering to the hole in the canal, and upon the top of this stone was set a hollow iron body, formed exactly like a pineapple with leaves. In the centre of the pine was the grate, and the top with the leaves being separate in the manner a pine is usually cut in that part, the coal was put into the pine, and the air was supplied for the draught through a number of small holes between the leaves, not to be easily noticed."*

FIG. CLXXV.



The stove that the doctor himself described for burning its own smoke, had the same general arrangement as the preceding, but with some ingenious additions to increase its heating effect.† Fig. CLXXV. is a horizontal section taken a few inches above the hearth; Fig. CLXXVI. a vertical transverse section; and Fig.

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* Theory of Chimnies, p. 26.

† Philosophical Papers, p. 61.

CLXXVII. a vertical longitudinal section; *x*, an opening in the cover of the stove, which has a hinge at *s*; *a*, fire-chamber, in which the grating is fixed; *b*, a space containing a second grating; *c*, ash-pit, with a drawer to receive the ashes; *d*, *e*, horizontal flues at each side of the ash-box, communicating with the vertical flues, *o*, *o*, which are carried into the chimney. The vase and flues are placed in a niche formed by closing up the fireplace; no communication is left between the room and the flue, except through the opening, *x*, in the lid.

FIG. CLXXVI.

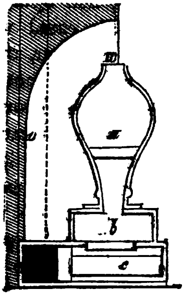
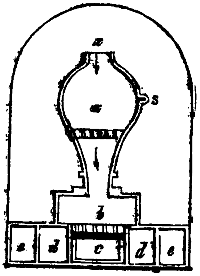


FIG. CLXXVII.



To use it, says the doctor, let the first fire be made after eight in the evening, or before eight in the morning, for at those hours there is usually a draft up a chimney, though it has long been without a fire—but between these hours in the day there is often, in a cold chimney, a draft downwards, when, if you attempt to kindle a fire, the smoke will come into the room; but to be certain of your proper time, hold a flame over the air-hole at the top of the vase. If the flame be drawn strongly down for a continuance without whiffling, you may first put in a few charcoals on the grate at *a*, lay some small sticks on the charcoals, and some pieces of paper on the sticks, and kindle the paper: then shut down the lid, and the air will pass down through the air-hole; blow the flame of the paper through the sticks and kindle them, and their flame passing lower kindles the charcoal. The flame and hot vapour, descending through the grating at *a*, passes into the chamber, *b*, and through the second grating in its bottom into the ash-pit, *c*: the hot vapour will then divide itself;—one portion will turn to the left and pass into the horizontal channels, *d* and *e*, and entering the vertical flue, *o*, will be conducted into the chimney. The other portion of the divided vapour will make a similar circuit on the left hand, in the channels, *d* and *c*, and entering the vertical flue, *o*, will also be conducted thence into the chimney. The surfaces of the vase and air-box, and the part of the horizontal channels exposed to the room are heated by these circumvolutions of the vapour, and the air warmed by contact with them spreads into the room. The larger pieces of coal that fall through the grating on the vase, are intercepted by the second grating, *e*, and the ashes fall through it into the ash-pit box, *c*.

The action of this well arranged apparatus, it is obvious, depends on an upward steady draught being maintained in the chimney flue, and therefore the ash-pit drawer and a door into the chamber, *b*, to withdraw the cinders, are to be made air-tight. Instead of depending on the common draught in the flue, at first lighting a fire, a small door may be made in the side of the flue to insert a piece of lighted paper, to produce an upward current at pleasure.

Burning fuel by the reversed flame is the only method which allows it to be supplied to a fire with the most perfect effect and precision; but, although a great number of schemes have been tried to burn smoke and save the coals which are wasted on the common method, only one attempt, and that exhibited little skill or ingenuity, has been made since the doctor's time to turn Daslesme's contrivance to a practical account.

In the infancy of gas lighting, Mr. Warner, a Saxon gentleman, proposed that cottages and farm-houses should be lighted as well as heated from the same fuel and stove. He enclosed the fresh wood in a retort placed over the fire-chamber, and conducted the gas into purifying vessels, and finally into pipes perforated with small holes, where it was inflamed to light the kitchen or bedroom. The surface of the stove in which this process was going on, heated the room effectually; and instead of the cottager losing the whole cost of the fuel consumed, the ligneous acid, oil, and tar produced by the distillation, was equal to half the value of the wood; the expense of lamps and candles was saved, and there was residue of charcoal. Even where the gas light was not desired, still this process he affirmed was economical, for he returned the gas and burned it under the retort, and cooked by gas flame. Another advantage of this stove was the facility it gave of "preserving and smoking meat in a purified smoke, instead of having it dirtied and impregnated with the soot and resin of the fuel in common chimneys." Considering the period in which his apparatus was designed, it displays much ingenuity, but a general notice of it may now be considered sufficient, if it should stimulate some genius to revive the scheme, and invent an apparatus that will combine the modern improvements in gas lighting, warming, and ventilation. About the same time, Mr. Stephens of Dublin described a method of saving fuel wasted in another process. Where lime is burned, an immense quantity of heat is dissipated in the atmosphere that might be eco-

* Sonini's Jour. 1806. Rep. of Arts, Vol. V. p. 36.

nomically applied to some domestic purpose. Fig. CLXXVIII. is a section of a small kiln, *a*, in which the lime to be calcined was placed, and all the hot gaseous vapour expelled from the minerals was made to flow into a flue, *c*, and thence into flues arranged to heat a room or a greenhouse. Fig. CLXXIX. is a section of the same kiln, constructed like a hot air stove: *a*, the kiln; *s*, the grating which is withdrawn to remove the calcined lime that falls into the pits; *c*, door at which it is introduced; *n*, *n*, channels for the admission of air into the space left around the kiln; *v*, an aperture at which the warmed air issues into the distributing flue.

FIG. CLXXVIII.

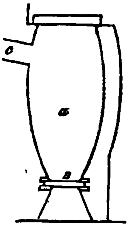
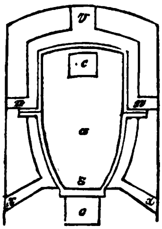


FIG. CLXXIX.



The method adopted in Copenhagen a few years ago to heat some public rooms in the War Office, was by placing 48-pound cannon balls, made red-hot, in iron boxes of fine sand, which were put under the seats of chairs and tables: when the windows and fireplaces were carefully stopped, the warmth thus communicated to the sand kept up in the apartment a heat of 60° F. for nine hours. The Copenhagen journalist gave no account of the manner of heating the balls, nor of the means by which they or the boxes were conveyed into the apartments; and, therefore, it is to be considered more as a scheme that *might* be practised by warlike men, than one in actual use. The same may be observed of a method mentioned in the public journals, about the same time, of an American engineer, who warmed his factory by means of the friction of two large circular plates of metal, that were pressed against each other and made to revolve with great rapidity. They were placed in an underground chamber carefully closed, into which the air admitted from without was rapidly heated by coming in contact with the hot discs, and was then conveyed by tunnels into the various rooms of the building. The size of the discs, the speed at which they revolved, the power required to move them, the heat produced, and a variety of other data, were given with laudable fractional minuteness. The journalist, naïvely enough, however, observed that one objection against this apparatus was the water-wheel being often stopped by frost when heat was most wanted; and if the discs were driven by steam, it perhaps would be found as economical to burn the same quantity of coals or wood in stoves as would be required to move the engine.

In many countries, as observed in a previous Essay, stove-heated rooms and a nauseous artificial climate are universal. The nose, although an organ of infinite sensibility in every region, and capable of perceiving the presence of offensive matters where the most delicate chemical tests fail, is nevertheless easily blunted, and what at the first impression feels pre-eminently disgusting, quickly becomes inoffensive. From habitual immersion in a polluted atmosphere, the Russ and others experience no inconvenience from gaseous putridity. The constant escape and renewal of a certain portion of heated air is only to be procured at the expense of a certain quantity of fuel, which neither his means nor the country are adequate to supply, but this has no possible connection with the *salubrity* of stove-heated air, or its production by the stove.

Dr. Burton noticed that the Germans make their stoves to open from the outside of the room, and that it was the custom of their servants to rise earlier, by some hours, than the rest of the family, to light the stove, that the room might acquire an equable temperature previous to their entrance to it. The heat was always kept nearly at 65°, and instead of crowding round the fireplace, as in England during winter, the company sat dispersed in different parts, as we do in summer. The reason is obvious, every part of the room was equally warm. "But," continues the doctor, "I can testify that in German rooms there is a closeness of feeling to a person accustomed to free air, which is unpleasant, if not unwholesome—no change of air, the windows closed as tight as can be, and the door fits as exactly as the carpenter can make it. The stove is air-tight, with regard to the room, and there is nothing to occasion a current like an English open fire. The apartments of the sick almost invariably smell disagreeably. I do not, however, recollect seeing a single ventilator in Germany, but I have repeatedly seen double windows."* In the cold weather most people everywhere are remiss in keeping a ventilator open which occasions a present inconvenience, and when constructed to be closed and opened at pleasure it is not to be confided in.

In England, where fuel is plenty, and its waste universal, the prejudice against stoves is strong and general. "Three years ago," says the scientific chief of the anti-stove faction, "I erected, in a spacious bed-room of my own house, a stove which was never heated so high as the boiling point of water, but which allowed *no* circulation of air by the chimney, except the small quantity which was admitted very near the hearthstone for supporting a *slow* combustion in the fuel. Every thing seemed comfortably and philosophically arranged. The temperature of my room was nearly the same night and day, from 55° to 60° F. In a short time, however, my natural vigour of body and mind began to give way. My sleep became disturbed, my appetite declined, a furious cough with pains in the chest supervened, without having been preceded, however, by any of the usual symptoms of catarrh, and my bowels were obstinately constipated; for this general distemperature, which continued for several months, my kind medical friends prescribed a vast variety of remedies, such as blood-letting, blistering, cupping, expectorants, anti-spasmodics, emetics, diaphoretics, mercurial alteratives—a pharmaceutical ordeal which I underwent without any material benefit. At length I discovered that the main cause of these disordered functions was a peculiar state of the blood, caused by breathing an atmosphere not sufficiently renewed, in consequence of a nearly air-tight stove apparatus. I now caused the stove to be removed, a fire to be rekindled in the open grate, took a strong dose of purgative medicine to remove the hepatic secretion, and within three days of this change of plan I felt myself a new being—the powers of my body and mind resumed their wonted alacrity, in which state, thank God, they have ever since remained—chiefly owing, I have no doubt, to unembarrassed ventilation in every part of my house, and the suppression of stove malaria."[*]

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* Essay on Regulated Temperature, p. 137.

In this assuredly grave case, strongly put, by one who is familiar with the chemical points bearing on the question, it must be confessed that the "great stove itself" seems cruelly treated; for it is clear to demonstration that the supposed malaria was not produced from injudicious construction, or inherent defect in the heating apparatus, but from the want of a small hole, having an area of about 3 inches, placed near the ceiling, in any part of the room, to emit the air contaminated by respiration, and other causes. Without this simple addition, all the evils attributed to the stove, would have been greatly aggravated, and the same deleterious malaria would have annoyed the philosopher, had his beloved steam-pipes, or a surface heated by hot water, given warmth to the apartment. Mr. Jeremy Bentham, in his "Panopticon," notices another source of stove malaria, but, liberal and just in this as in every thing, he exonerates the oppressed air heater from reproach: a bad smell, he says, often arises in consequence of people spitting on the stove to try if it be hot; but this "nasty, offensive and unmannerly practice," he suggests, should be reckoned unfashionable, and be remembered to the discredit of the spitter, and not be urged as an objection against the spittee.

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[*] Architectural Mag. vol. v. p. 38.

In England, the surface of the stove is almost always overheated, and the vegetable and animal matter at all times floating in the air of a room, coming in contact with the hot surface, may be roasted or burned, and emit an unpleasant odour; or when the stove, as is frequently the case, gets red-hot, it may decompose the air itself. Being usually constructed to open into the room, the gaseous matters also of the fuel sometimes escape at the door of the fire-chamber, but the same annoying and unwholesome effect is produced by open fires. When it occurs with stoves, it may generally be referred to imperfect workmanship. Stoves, however skilfully constructed, are also blamed for depriving the air of its moisture, which produces headache and unpleasant sensations in the nose and throat, which means only that when cold air is heated, it is expanded, and has less moisture in the same bulk, than it had before undergoing the process, for the same effect is produced in an equal degree by steam or hot water pipes, and by every method of heating. In fact, if that portion of the air of a room that is heated by an open fire was not whisked into the chimney before it rose to the nose, it would generally be most offensive. The heat radiating from the glowing coals and heated surfaces about the grate, is absorbed by the rug and carpet and furniture, and by the clothes of the company. These substances, in their turn, heat the air in contact with them, and it is against all experience to affirm that their surfaces are as pure and free from noxious taint as those of a stove made of iron or porcelain.

It is, however, essential to the economical effect of a stove, that the room be nearly air-tight, and permit no heated air to escape, except what is vitiated by respiration and other causes, or thought necessary for wholesome ventilation. In apartments with ill-fitted rickety doors and windows, and a large extent of ill-glazed surface, and thin, heat-absorbing walls, abounding in wind chinks—or in general in all cases where the apartment approximates to the exposure of a field, as many English rooms do,—an open fire is to be preferred. Those who stand round a fire in a field receive as much heat as if they stood before it in a room, and in a room no more than if they were in a field. In a field or field-like room the same fire in a stove would be useless.

ESSAY XIII.

THE way in which large buildings or rooms were formerly heated, particularly for manufacturing purposes, where open fires were inadmissible, was by a sort of Dutch stove formed of a large cast or wrought iron vessel, generally square and set upon a foundation of brickwork, that enclosed a furnace; and this apparatus was placed in the room to be heated. As far as economy of heat went, this was a great advance on the system of open fires, but it was found to be unhealthy and dangerous; and a large proportion of the accidental fires which, in former times, destroyed many factories, originated from ill-constructed stoves. The cockle was placed in a large area, but the air of the room not carrying off the heat from the surface so fast as it was produced, it was often red-hot; the great heat rendering all the adjacent wood-work very combustible, when the stove cracked, or a joint opened, or any inflammable substance came into contact with the stove, a conflagration was inevitable.

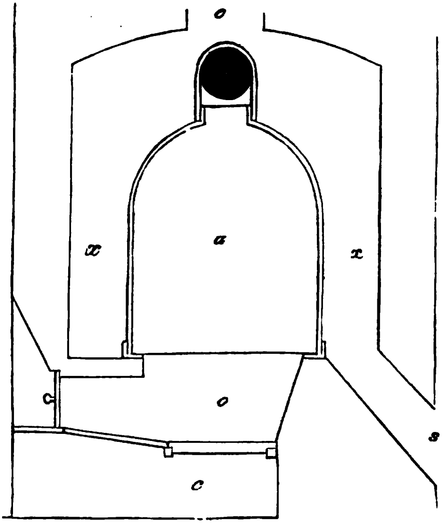
The best use made of this apparatus was in refining-houses for drying sugar.

The next step was to place the cockle, or kakle, as Mr. Laing writes it, in a separate chamber adjoining or under the room to be heated; the external air admitted into this room came in contact with the cockle surface, and was heated and conducted by a pipe or channel into the building. The smoke was carried by a pipe in the top of the cockle into a brick flue rising above the roof. This variety of apparatus is still extensively used, but more attention is paid to prevent its being overheated, by giving a better proportion to the fire and the cockle.

Mr. Strutt, whose method of ventilation by a descending current has been noticed in a previous essay, about 1792 observed that in stoves on the construction like that which has been described, "the combination of the heat from the fuel with the air was effected very imperfectly, on account of the latter being a bad conductor and incapable of being heated by radiation. The particles of air only which are in absolute contact with the iron are warmed by it, which, ascending in consequence of the decrease of its specific gravity, are replaced by others, but so slowly in comparison with the quantity of heat absorbed from the fuel, that the cockle is covered as it were by a blanket, and quickly becomes red-hot;" Mr. Strutt therefore thought, that by enclosing all the air to be heated in a perpendicular tunnel of considerable height, and by this means bringing it nearer to the cockle, the current would, by having this direction given to it, keep the surface of the cockle cooler, and be itself raised to a higher temperature.

An apparatus constructed on this principle is shown in section in Fig. CLXXX.: *c*, the ash-pit; *o*, the fuel chamber, 14 inches deep from the surface of the bars to the base of the cockle. The grate bars were 13 inches long between the bearers, and the air admitted by three spaces between them. The cockle, *a*, was square on the plan, 30 inches on the side, and had 88 square feet of surface, and was 2 inches thick, and cast with a projecting faucet on its roof to receive the smoke-pipe, *i*, 8 inches in diameter, so as to overlap about 3 inches. It was set on an iron rim, as shown in the figure, 2 inches thick, 4 inches broad, and 3 inches high, which was bedded on the brickwork. A space, *x*, 10 inches wide, was left all round the cockle, and arched at top, and had an opening, *o*, 12 inches square, through which the heated air was conveyed to the building. The cold air was admitted into the space, *x*, on three sides of the cockle, by the channel, *v*, which was constructed to give the entering air a direction so as to make it impinge on the surface of the cockle. The fireplace door fitted very accurately, and the ash-pit was enclosed by a door in which was a sliding valve to regulate the admission of the air. The cold air channel, *x*, was connected with another channel opening to the air on the level of the floor of the ash-pit, but by turning a valve this aperture was closed, and another opened that communicated with a perpendicular dry well terminating 23 feet under the level of the ash-pit. The cold air was admitted from the well when the cockle surface was

FIG. CLXXX.

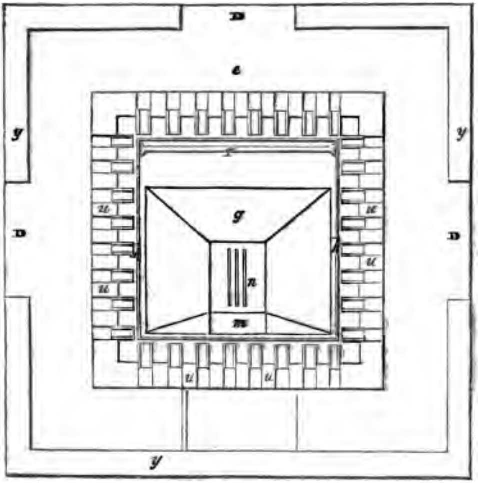


becoming too hot, and from the greater velocity thus given to the ascending air a much larger quantity impinged on the heating surface, which by this means had its temperature lowered. The same expedient was resorted to when a brisker ventilation than usual was required. This was a much more effective apparatus than the cockle placed as usual in a room; and although it was not practicable to bring even the greater portion of the air into contact with the stove, still it comfortably warmed 19,200 feet of space, keeping it at 68° with an ample ventilation, when the air out of doors was at 25° F., which was nearly 329 cubic feet of space to 1 square foot of heating surface; and burning 27 lbs. of coal an hour.

Mr. Strutt subsequently applied his principle in a still more effective way. He enclosed this perpendicular wall within another wall, leaving a distance of 14 inches between them. And he divided this outer enclosure into nearly equal portions in its height. The inner wall, which was 9 inches thick, and placed at a distance of 7 inches from the cockle, he formed with openings like a honeycomb, through which the cold air rushed from the air-chamber and impinged on the cockle. He afterwards placed a wrought iron tube in each hole of this honeycombed wall, which reached to within a quarter of an inch of the cockle, by which means all the air admitted came twice into contact with the heated metal, and issued into the room at a temperature of 120° F. In 1806 an hospital at Nottingham was heated by a stove constructed in this manner. It was placed in a small apartment, about 17 feet below the wards to be warmed. The cockle was of wrought iron, ⅛ of an inch thick, 4 feet on the side, and 5 feet high, having about 73 square feet of heating surface. The building, containing 200,000 cubic feet of space, enclosed with walls perforated with a great number of windows, was kept at a temperature of 60° F., night and day, from October to May, with an expenditure of 448 lbs. of coal daily;* or each square foot of surface kept 2739 cubic feet of space at the temperature of 60° with about 18·7 lbs. of coal an hour; if there be no error in the report.

The stove shown in the following figures was designed by Messrs. Boulton and Watt, to heat a museum, and erected in 1808. The greater part of the following description formed the specification drawn up by these distinguished engineers for the guidance of their workmen who built it. Fig. CLXXXI. is a horizontal section taken a little above the level of the pavement of the cold air chamber. Fig. CLXXXII. is another horizontal section taken below the roof to exhibit the dome of the stove as it would appear when looking downwards at it. Fig. CLXXXIII. is a vertical section taken through the centre of the stove; and Fig. CLXXXIV. is also a vertical section taken

FIG. CLXXXI.



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* Edinburgh Medical and Surgical Journal, vol. iv. p. 17.

FIG. CLXXXII.

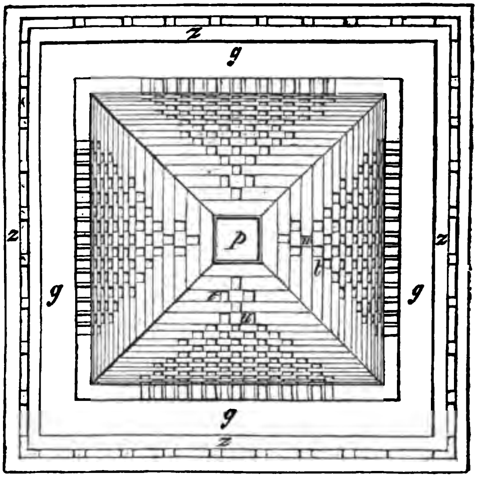
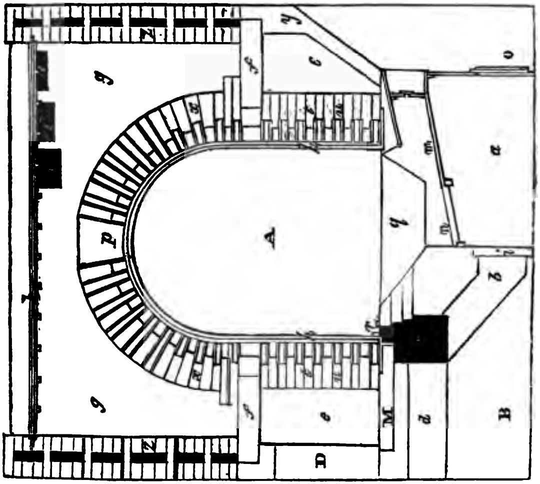


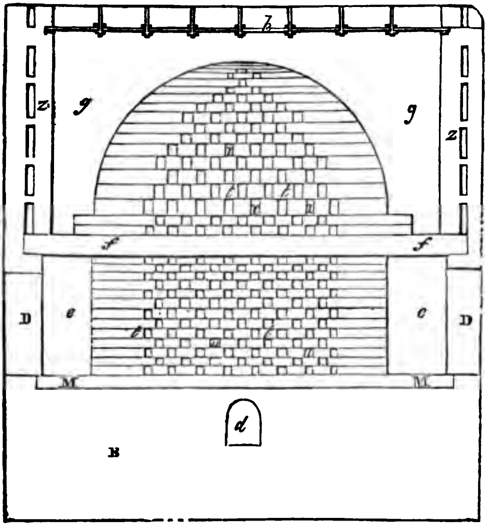
FIG. CLXXXIII.



through the air-chamber, to show the honeycombed wall in elevation. The same letters in these four figures are placed on the same part.

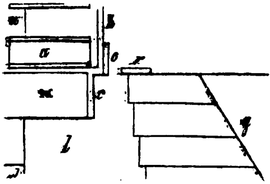
The cockle, *h*, 5 feet square, is made of rolled iron plates ¼ inch thick. It is 4 feet in height from its sole to the springing of the arch, to which height the sides are perpendicular; at this point the dome commences, which is semicircular in each direction; it is open at bottom, and placed on the brickwork, *n*, containing the fireplace. The bottom of the cockle has a rim or ledge 10 inches wide, on which it stands. Where it stands over the flue it has a piece of iron plate, *o*, riveted to it, which projects downwards, *c*, the depth of the pavement, M, of the cold air chamber, to protect the edge of the stone from the action of the smoke; and it is further considered to be useful as lining the smoke-slit with a substance not liable to be da-

FIG. CLXXXIV.



maged by the insertion of the crooked poker, which is drawn backwards and forwards occasionally to clear it of the soot which may adhere at the sides, and diminish the opening. The smoke-slit is about $\frac{1}{2}$ inch wide, extending the whole length of one of the sides of the cockle, and formed by the regulating iron bar, *r*, which has a notch upon each end, as shown in Fig. CLXXXV., and slips down upon a projecting piece riveted to the stove at each end; if the slit, which should be a little more in area than the sum of all the slits in the fire-grate, is too large or too small, it can be adjusted by altering the projecting pieces.

FIG. CLXXXV.

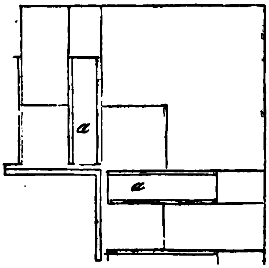


In placing the cockle great care should be taken not to disturb the joints of the pavement of stone or brick on which it is seated; and before the perforated wall is begun, a fire should be made in the fireplace to ascertain whether all the joints are smoke-tight.

The fireplace is 18 inches wide and 21 inches long. The furnace has two common furnace bars and two broad bars or side plates, which form three slits from $\frac{3}{8}$ to $\frac{1}{2}$ inch wide and 16 inches long. A greater area for air must not be given to the fire until it is ascertained from trial whether that will be sufficient to produce the proper draught in the chimney, so as to heat the surface of the stove sufficiently, but every chance of the fire-man being able to make the stove red-hot, or even to raise it beyond 180°, must be avoided. The dead plate, *m*, and fire-door, complete the fireplace. The door has a hole with a slider, at which a very small quantity of air is admitted, which is found to assist the combustion. The dead plate, *m*, Fig. CLXXXIII. on which the fuel is placed to be pushed forward on the grating, may be sloped as in the figure, or laid flat; its sides are built about an inch into the wall, and its end rests on the bearing bar. In small furnaces this plate and its cheeks and top are cast in one piece, which makes a better finish than having them separate. The ash-pit door has a similar opening with a slider in it, which is useful to diminish the intensity of combustion in particular states and direction of the wind. Great care is required to make these doors and valves fit as closely as possible, that all air may be excluded from the stove but what passes through the valve opening.

The perforated or honeycombed wall, *u u*, placed at a distance of 6 inches from the sides of the cockle, *h*, is 9 inches thick, and continued archways over the iron dome, from each of the sides, to form a groined arch. The bricks are 5 inches broad, 2½ thick, and 9 inches long. Those for the arches being rubbed to the proper radius, 5 inches broad, and 2½ inches thick at the narrower end. All the bricks are laid with their ends toward the cockle, and in each course, between every two bricks, a space is left in which is inserted a tube of thin sheet iron that reaches to within ¾ inch of the cockle, and having about 2 inches lap of the brickwork. The bricks of the second course are laid over the iron tubes of the first course, and so on alternately in the other courses. The air-tubes are 2 inches wide, 2¾ inches deep, and 7¼ inches long, and made of black rolled iron, of the thickness of common tin plate, with a lapped joint in the lower side. At the angles of the stove they should be inserted about 4½ inches into the wall, as shown in Fig. CLXXXVI. The tubes are cemented into the brickwork with some fine plaster lime,

FIG. CLXXXVI.



and great care taken that none drop into the space between the perforated wall and cockle.

The arched dome of the perforated wall is carried up equally on the four sides to the fifth or sixth course, when the bricks may require some support to prevent their sliding inwards, and should be bedded in fine, but stiff mortar. As the dome when finished may sink a little, the end of the tubes of the fifth and following courses may be kept a little further than ¾ of an inch from the dome surface of the cockle; 1¼ inch will be found a sufficient distance when the dome has been properly constructed. In some cases a failure ensued from the air-tubes of the dome getting loose, and slipping down upon the surface of the cockle; to prevent this, and also to bind the work, the air tubes of the sixth and following courses of the dome are made 14 inches long, as *c*, in Fig. CLXXXVII., with ears or flaps, Fig. CLXXXVIII., about ½ inch broad at their outer end, which lie on the outer face of the wall. If they are made without flaps they should be at least 2 inches longer than those in the perpendicular walls, and if formed to radiate to the centre like the bricks, the work will be firmer and better. In the crown of the dome is left a large opening, *p*, 14 inches square, which also has an iron air-tube of that size reaching to the same distance of the surface as the small tubes. It is obvious that there should not be a less number of tubes in the upper half of the stove than in the lower half.

FIG. CLXXXVII.

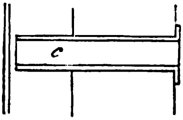
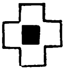
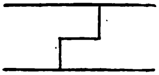


FIG. CLXXXVIII.



The cold air chamber, *e*, which surrounds the perforated wall, is 41 inches high, and of any width that is convenient; it is shown in the figures about 15 inches wide, but in the Museum stove it was 29 inches wide. The pavement, *f*, forming its roof, and the floor of the warm air chamber, *g*, is of stone 6 inches thick, with a

FIG. CLXXXIX.



rabbet joint, and inserte about 4 inches into the perforated wall, and 4 inches in the enclosing wall, *y*, and carefully pointed with fine mortar, to prevent the admission of cold air through crevices into the warm air chamber, which would impair the effect of the stove. To prevent the dissipation of heat from the hot air chamber, the outer wall, *z*, is built hollow; two 4½ inch walls, with a space of 4½ inches between them, are tied together with single bricks laid lengthwise across the space at certain intervals, one brick in each square foot of the vertical face of the wall being sufficient. On the top of this hollow wall is laid the iron ceiling, which consists of thin iron joists of strong grey cast iron, and soft enough to be drilled and tapped, with knobs at their lower edge. The distance of the joists being regulated by the width of the sheet iron that can be procured, two sets of thin iron bars are screwed to these knobs, which embrace between them, as shown in the figure, the edges of the thin iron plates laid edge to edge between the bars, with notches in them to admit the screws. The plates overlap each other about 2 inches at their ends.

The holes in the bars are made easy for the screws to allow for their expansion, and for the same reason their ends, if they are in lengths, must not touch each other. The joists are laid upon a piece of iron plate bedded on the hollow wall. When the ceiling is screwed up to the joists, and the joints made good with a little plaster lime, the whole is filled up, 9 inches deep, with coal ashes from a house fire, sifted through a fine sieve.

In lieu of iron plates common wooden laths might be screwed in between the bars below the joists, and plastered above and below, without danger of their burning, as there would be no access of air to them, but the economy would be but trifling.

If convenience permitted, the cold air should enter from every side of the stove, but where from local causes that cannot be practised, and the air enters from opposite sides, the communication of the cold air flue must be interrupted by a wall.

The smoke-flue, *d*, is arched with a brick on edge, covered with the stone paving or brick, *m*, of the cold air chamber, and made smoke tight, and great care is necessary in setting the cockle not to disturb the joints. A flue is made from the ash-pit into this smoke-flue for the convenience of introducing a scraper to cleanse it from soot. Its opening is carefully closed with a tile, and pointed with mortar as often as it is replaced after this operation. The ash-pit is enclosed with a door fitted with a sliding valve, to admit the air to the fireplace.

Apertures, *i i i*, are made in the side of the hot air chamber which open into the tunnels or pipes conducting the heated air into the different stories of the building. Valves are fixed in them in each story to regulate the quantity of warm air admitted; but these valves must not be capable of shutting up the warm air passages entirely, otherwise at times for want of a sufficient circulation the cockle might get red-hot. An opening left round each valve, of about ½ square foot, would be sufficient.

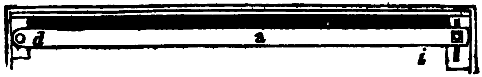
Foul air chimneys must also be made in each apartment into which it is intended to introduce the hot air, otherwise it will not enter. Each has the same area as the aperture by which the heated air is admitted, and is also fitted with a valve, that is fully opened before any fire is made in the stove.

In some convenient part of the smoke-flue there is a sliding damper, and a small opening fitted with a door that shuts closely, the use of which is to introduce some lighted paper or straw to produce a draught at first lighting the fire, which otherwise would not act immediately.

When the fire is lighted in the furnace, the smoke fills the cockle, and a portion of it then begins to pass downward through the smoke-slit into the flue, *l*, that runs along the side of the stove, and thence it flows into the horizontal flue that is connected with the chimney. In the meantime the cockle becoming hot warms the air in the surrounding space, which rises upwards and passes through the tubes in the perforated wall into the hot air chamber; and the air entering from the cold air chamber is conducted by the air-tubes close to the sides of the cockle, and blows against it like a bellows, and rises in its turn with a greater or less velocity, according to the heat of the iron surface it impinges on, through the hot air tubes in the groined arch into the warm air chamber, and thence through the apertures, *i i i*, into the spaces to be heated.

In some stoves both sides of the smoke-slit are lined with iron plate, and instead of notches in the end of the regulating bar to slip, as has been described, upon a knob riveted to the side of the stove, the bar, a, Fig. CXC., turns on a joint, *d*, and the other end is fitted with a pin sliding in a groove, which is screwed down when the slit is adjusted.

FIG. CXC.



In all cases where practicable, the openings of the hot air channels to the room should be near the floor, and the opening of the foul air flue near the ceiling, and opposite each other. In a room 140 feet long and 37 feet wide, and 9 feet between floor and ceiling, where one large hot air flue only opened near the floor in the middle of the side at one end, and the foul air flue near the ceiling in the middle of the opposite end, no part of the room differed on the same level more than 4° F., and what was least expected, the further end was generally 1° or 2° warmer than that nearer the hot air aperture.

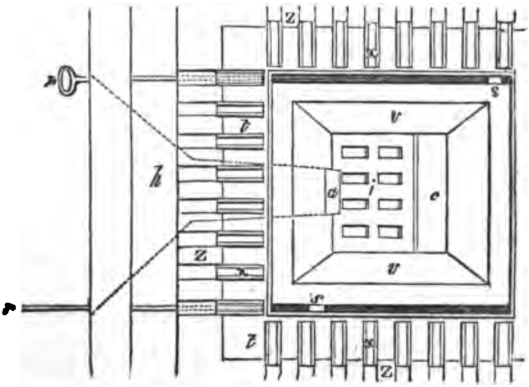
In large buildings where workmen are employed it is advisable to place the register in the hot air tunnel, or in the foul air tunnel, where it cannot be altered; in cold weather, without this precaution, it is often very difficult to equalize the heat in the upper and lower stories.

If it be necessary to form these valves so as to be able at any time wholly to exclude the warm air from the building, or from a part of it, a separate channel must be provided, opening outwards to allow a current of warm air to ascend from the stove, to carry the heat from its surface and prevent the cockle becoming red-hot. From not attending to this, cockles are liable to be overheated and crack, and the smoke and flame issues into the hot air chamber and finds its way into the building. If the cockle is of wrought iron and remains sound, it warps with the heat and forms cracks and fissures in the joints of the perforated wall and in the brickwork on which it is seated, which occasion the same danger to the building as a crevice in the cockle itself.

As a means of preventing the flame accidentally issuing from the stove into the building, the apertures, *i i i*, in the hot air chamber, may have a valve, hung on a joint and so loaded as to fall by its own weight and close the aperture; the cord attached to it passes *across* the opening, and has a weight at its extremity sufficient to keep the valve in its position. Should the flame by any means penetrate into the air chamber in passing into the warm air flue, it would burn the cord to which the weight is hung; and the valve, being then deprived of its counterpoise, would fall and close the opening.

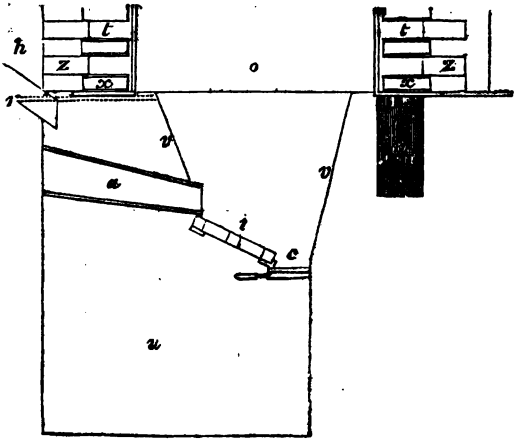
In a stove erected from Mr. Strutt's design in an infirmary, the fireplace had a somewhat different form from that designed at Soho. Fig. CXCI. is a horizontal section of this fireplace cut by a plane passing through the second tier of air pipes; and Fig. CXCII. is a vertical section through the centre of the ash-pit; *a*, is a four-sided tunnel or mouth piece; *i i*, the grate bars; *c*, a frame containing a sliding plate to let out the cinders and other refuse into the ash-pit; *u*, the ash-pit, which is not enclosed; *v v*, the sides of the hopper-shaped fireplace; *o*, the cockle; z, the per-

FIG. CXCI.



forated wall; *t*, the space between it and the cockle; *x*, iron air tubes, or earthenware pipes, reaching to within ¾ of an inch of the side; *h*, cold air chamber; *n*, smoke-flue. On the right and left of the fire-place is a bar of cast iron extending the whole length of each side, and placed at a distance of ½ an inch from the side of the stove, forming a narrow opening of that size into the smoke-flue under the flanch of the cockle. To clear this narrow opening of the soot adhering to it, two rakes, *r*, *r*, which slide in sockets riveted to the cockle, have projecting pieces, *s*, *s*, which

FIG. CXCII.



fit the opening or smoke-slit. Every time the fire is mended the rakes are drawn backward and forward, and the projecting pieces scrape the smoke-slit and keep it always free of soot.*

Where practicable, cold air to supply the stove should be drawn from a large underground tunnel, as practised by Mr. Strutt in the Derby Infirmary.* By this means, when the external air is at the freezing point, the tunnel will furnish air at nearly the mean temperature, by which a considerable portion of heat may be saved. The entrance of the tunnel where it opens to the air should have a turn-cap with a vane placed so that its mouth will always be presented *to* the air, which insures at all times a supply to the cold air chamber.

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* Sylvester. Phil. of Domestic Economy, pl. II.

The section of this tunnel should be square, as exposing the greatest surface to the cooling influence of the ground in which it is formed; and it should, if possible, be lined or cased with some substance that is a good conductor of heat, in order that in winter the warmth of the earth may be propagated rapidly to the air flowing through it. Where the quality of the air near the surface may, from any cause, be considered less pure than at a greater height in the atmosphere, the entrance to the tunnel may be a low tower—or a flue may be made to open high up in a wall, and carried downwards into the cold air chamber.

Mr. Sylvester observes, that it is essential to the principle of Strutt's stove, that it should be placed considerably below the lowest room to be warmed,—from 15 to 20 feet, where it can be obtained, reckoning from the bottom of the cold air chamber upwards,—to increase the velocity of the heated air. It is also better to heat a large quantity of air through a small number of degrees, than the contrary. When only a small quantity of air passes through the stove, the cockle is in danger of being overheated. Mr. Sylvester says, the cockle surface should not rise above 280°; beyond this it has a tendency to injure the materials of which the flues are formed; it is also heated with less economy,—since, as has been observed, the smoke will pass away at a higher temperature. The temperature of the surface he recommends is, however, a great deal too high; and much of the prejudice against stoves has arisen from this circumstance. Were the surface never to exceed 130°, although the size of the stove would be increased, the salubrity of the air as well as economy of fuel would be greatly increased also.

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* See p. 87.

The effect of the Museum stove, which has been described, was not further observed than that it produced a current of air varying from 73° to 81° where the external air was 33°, and that the temperature could be raised to 93°.

A stove on the same construction in all its details, 6·5 feet high and 5 feet on the side, with 118 square feet of surface, was found sufficient to warm 56,376 cubic feet of space to 57°, when the air out of doors was at 29°.

In a factory containing 187,004 cubic feet of space, the two stoves had 316 square feet of surface, and maintained the air at 61°, when externally it was 35°.

Two stoves with 327 square feet of surface warmed 209,000 cubic feet.

In a drying stove where the temperature was 104°, the heating surface required was 1 foot to 76 of cubic space.

By a small experimental stove with a heating surface of nearly 15 square feet, Mr. Sylvester kept 4500 cubic feet of air at 21° above the atmospheric temperature with 5 lbs. of coal an hour; and by the same apparatus he raised 5086 cubic feet of air, or 339 lbs., 59°, which is equal to 20,000 lbs. raised 1° with 1 lb. of coal. In another experiment he raised 22,400 lbs. of air 1° with the same quantity of fuel.*

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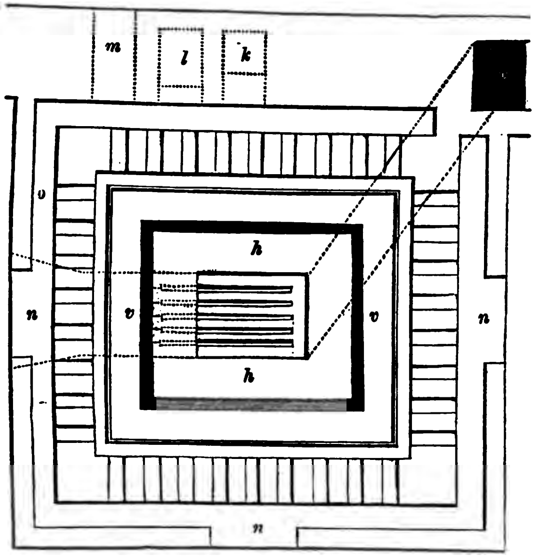
* Mr. Sylvester observed that "it was most remarkable that, although this stove was in use as early as 1792, and free to the inspection of any inquirer, and the proprietors always willing to give

The stove of which Fig. CXCIII. is an horizontal section, and Fig. CXCIV. a vertical section, was erected by the late Mr. Murray of Leeds.

FIG. CXCIII.



The fireplace, *a*, placed at the bottom of a brick tunnel, *h h*, is 19 inches long, 15 inches wide and 45 inches high above the furnace bars, which are 26 inches long, and laid horizontally; two of them being

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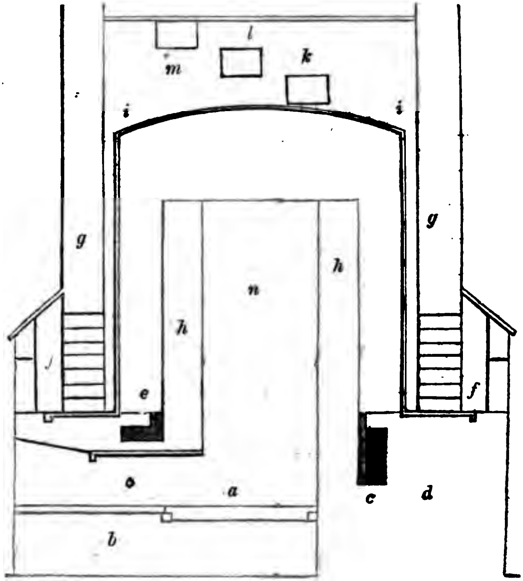
information for its construction, yet it was not once noticed in any publication, and was adopted in but very few instances."—Philosophy of Domestic Economy, p. 22. In this, however, he was misinformed. Many stoves in 1808, and afterwards, were erected, and an account with engravings has been quoted that was published in that year.

¾ of an inch broad, are placed in the centre, and with the two side bars form three slits, each about ¼ of an inch wide; the height of the opening of the mouthpiece being about 10 inches, and its width that of the brick tunnel. The cockle, *i i*, placed at a distance of 9 inches from the tunnel, is ⅜ inch thick, of plate iron riveted together like the boiler of a steam-engine, with a flat-groined top. This cockle has a rim all round its open end, 13 inches broad, turned down about an inch at its edge as shown in the figure, which is seated on the brickwork 17 inches above the upper surface of the furnace bars, *a*. The smoke-flue,

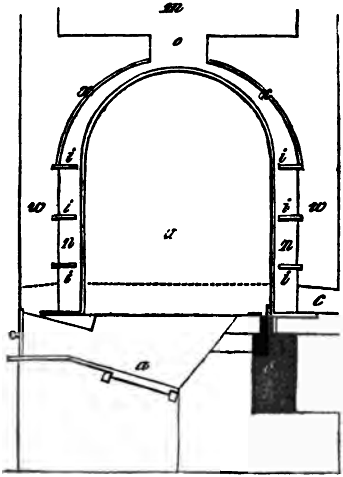
FIG. CXCIV.



c e, is formed all round the edge of the cockle, having the smoke-slit also carried round, as shown in Fig. CXCIII. At a distance of 3 inches from the cockle is a 9 inch wall, *g*, built upon its rim or ledge, and rising to the height required to form an air chamber. The lower part of this wall has 7 perforated courses, similar to those in the Strutt stove, but without iron tubes. Beyond this wall, at the distance of 6 inches, is another wall, reaching only about 7 inches above the upper perforated course, and covered with tiles; its intention being to prevent the drifting of the rain or snow into the honeycomb openings, and exclude the high winds which prevail in the exposed situation in which the stove is erected. In the middle of each side of this low wall is an opening, *n n*, 16 inches long and 10 inches high, which admits the external air to the perforated wall. The smoke-flue, *c*, communicates with the chimney, *x*, in the direction shown by the dotted line proceeding from it; openings are made in the side, by which access is had to the smoke-flue when it requires cleaning; and which is carefully stopped and luted after each operation; *k*, *l*, *m*, are the apertures at which the air from the hot air chamber enters the tunnels that convey it to the different floors of the building. The practical defect in the stove is the difficulty of cleaning out the space between the internal wall and the cockle. The effect was considered to be superior to that of a common cockle, but the temperature of the stream of air was irregular, and the top of the cockle was often over-heated.

The stove, of which a vertical section is shown in Fig. CXCV., and a section through the air chamber in Fig. CXCVI., was described by Mr. Meikleham in 1822. The fireplace, *a*, smoke-flue, *c*, smoke-slit and cockle, *n*, are on the same construction with the Strutt stove, as will be apparent from the cut. The cockle is 5 feet on the side, and 6 feet 6 inches high, and enclosed by a wall, *w*, placed at a distance of 6 inches on every

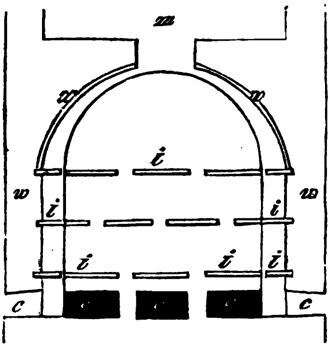
FIG. CXCV.



side. Deflecting thin iron plates, *i*, *i*, fixed in this wall, project within an inch of the cockle, each tier breaking joint as shown in Fig. CXCVI. At the springing of the dome this space begins to diminish, and near the opening, *m*, in crown of the arch, it approaches within 2 inches of the roof of the cockle. The cold air enters the space, *i*, by the openings, *c*, *c*, which are made in three of its sides, and in its ascent is brought in contact with the heated cockle by the tiers of horizontal plates, *i*, *i*, and is further kept in contact with its hot roof from the space diminishing through which it flows into the aperture, *o*, that opens into the air chamber, *m*, whence it is distributed to the building.

The under side of the dome was lined with thin iron plates, *x*, which being strongly heated by the radiation from the cockle, the air flowed as it were between two hot surfaces, and was considerably raised in temperature after it passed the retarding horizontal plates, *i*, *i*.

FIG. CXCVI.



This apparatus had 118 square feet of heating surface, and maintained a cubic area of 50,216 cubic feet at 59°, when the external air was at 31°.

The Chabannes' calorifère described in a previous essay, stands pre-eminent among stoves for its air roasting powers, but a modification of it introduced by Dr. Arnot at the Custom House, in which the temperature of the fire-chamber is regulated by his elegant and ingenious mechanism, becomes an economical as well as salubrious generator of heat. The stove placed in the long room is shown in plan, Fig. CXCVII. and in section, Fig. CXCVIII. The fire-chamber, *a*, is surrounded by twenty-two tubes, *t t*, which have the form of a flattened cylinder, with whose surfaces the air that circulates through and around the stove come in contact; *c*, smoke-flue descending through the floor; *d*, hopper or receptacle over furnace to contain a supply of fuel; *e*, boiler for evaporation, *f*, fire grating, six inches above bottom, two loose frames of bars supported at one end on a shifting leg, *g*, so that they can be let down if necessary to remove any obstruction from clinkers, and without extinguishing the fire. The sides of the fire-chamber are lined with Stourbridge lumps two inches thick. The ash-pit, *g*, forms a continuation of the bottom of the fire-box; and great care is required in filling up the ash-pit door, *h*, that it may shut quite close, so that no air may be admitted except through the pipe, *i*, on the back of ash-pit, for on this mainly depends the successful action of the stove. The mouth of this pipe has a valve, *k*, hung on pivots and nicely balanced, which is moved by the rise and fall of a float in mercury contained in a glass tube, *e*. The extremity of this tube, *e*, being inserted into the stove, the heat expands the air contained within the back part of it, and the mercury rises and falls with the

FIG. CXCVII.

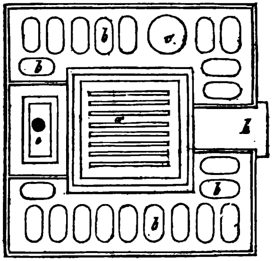
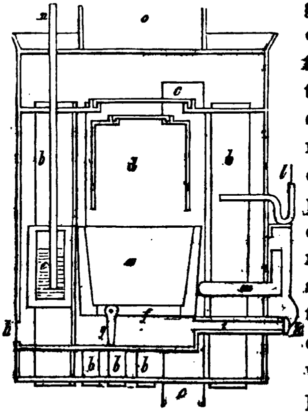


FIG. CXCVIII.



temperature of the stove; and is so adjusted that as the heat increases it closes the valve and checks the fire by admitting less air, and it opens the valve when the heat decreases.

The fuel is supplied from the top through an aperture under the square pedestal, which slides back. The outer lid, *o*, is made air-tight by a sand joint, and another lid is placed within. The hopper, *d*, is placed over the fire-box, *a*, leaving an interval of four inches between the top of one and the bottom of the other, for the escape of the air and gas rising from the incandescent fuel. The hopper diminishes the space for the accumulation of the explosive gases, besides insuring a more regular combustion, as the fire-box is always kept full, and the fuel descends upon it in a prepared state; *e*, an iron pipe six inches diameter for carrying off the smoke. Further to regulate the draught of the fire through the smoke tube, there is a communication made to it from the aperture, *n*, at the mouth of which a valve or flap is suspended, so that if the draught flags, the flap opens and admits the air through the tube which quickens it. When the draught is brisk it is checked by sucking the valve so close that no air can pass it. This valve is generally found in motion and serves to indicate plainly the force of the fire. The smoke tube is carried down through the flooring and then continued horizontally in another tube nine inches diameter, with the space between filled with pounded brick. Underneath the junction of the horizontal tube with the upright flue in the wall, there is a receptacle to collect the condensed moisture which is liable to accumulate. A *rotary blowing* apparatus is placed in the flue, a little above, in order to give the first impulse to the draught from the stove by exhausting the air in the tube below, and thus drawing down the smoke. The body of the stove is entirely exposed to the influence of the fire contained within it.

In a corresponding stove placed at the other end of the same room, the fire-chamber is carried up nearly to the top, and enclosed from the stove by a lid shutting into a sand groove, with a lesser one within it which is opened to admit the fuel; and if any gas is distilled it is prevented from passing into the general enclosure, and carried by a small tube at top into the chimney flue. The regulator of this stove is a bar of of brass lengthening by expansion, which gives motion to a valve formed of two discs, so hung together that as one is sucked close, another is opened. A third stove placed in the centre of the room has its pipe conveyed upwards through the ceiling. The iron and brass work of the three stoves weighs 6¾ tons.

The room in which they are placed is 186 feet in length, 64 feet in width, and 44 feet in height, containing about 519,376 cubic feet of space; and has thirty four windows in the sides and ceiling with 2100 square feet of glazed surface. The three stoves contain 800 square feet of heating surface, which is kept nearly at 137°; and the air of the room at 58° in the coldest weather. From seven to eight gallons of water are evaporated in 24 hours, and when heated to the fullest extent the three stoves consume 6 bushels of coke in 24 hours.* The effect of this apparatus, both as regards the production of heat and economy of fuel, is excellent.

From the position of the stoves on the floor and the low temperature of their surface, their radiation can be but trifling; on that account they might without detriment to their action, have been placed out of sight as the stoves were which they superseded. The display of their lumbering masses has much impaired the architectural elegance of one of the most spacious and handsome rooms in the metropolis.

Some years ago an old factory-heating apparatus which is shown in Fig. CXCIX. and Fig. CC.

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* Transactions of Institute of Architects vol. i. p. 169.

was revived by Mr. Perkins. In this the heat from the smoke rising from a middle-sized, cylindrical, iron-plate Dutch stove, was abstracted and thrown into the apartment: *a*, the stove, surrounded by a casing of thin sheet iron leaving a space, *t*, of 1½ inch round it, but open from top to bottom in front. The external air is introduced by the pipe at *z*, which blows over the hot surface of the stove into the room. In some instances the casing covered the half only of the stove, and where the air was emitted the casing approached to within ⅛ of an inch of the surface.

FIG. CXCIX.

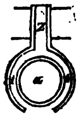
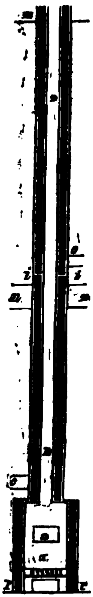


FIG. CC.



The smoke was conveyed from the fuel-chamber in the common way by a sheet-iron pipe, *n*, 6 or 7 inches in diameter, which passed through the ceiling, *n*, into the floor above, and into the third story, where it was inserted into the chimney. The smoke-pipe, *n*, was enclosed in a casing which left a space, *x*, about 2 inches all round, and the external air was admitted into the space by a pipe, *o*; openings, *i*, *i*, were made from the air space at the floor above, at which its communication from the outside with the lower air-pipe, *o*, terminated. Another pipe, *o*, was inserted into the casing above these apertures; and so on at each floor, if it continued to be carried upward. The air admitted at *o*, above the stove, rising in the space, *x*, was heated by contact with the smoke-pipe, *n*, and emitted into the room on the first floor at the apertures, *i*, *i*. The external air flowing into the space above these apertures was also warmed as it rose upwards by the smoke-pipe, and emitted above the floor in the third story in the same manner as in the floor below. In some cases the smoke-pipe was carried up in the flue and formed an efficient apparatus at a moderate cost. It is obvious that there would be a good ventilation with this apparatus, since as much air escaped from the room as entered it. The effect was not, however, so great as it ought to have been, from the perpendicular position of the smoke-pipe being unfavourable for bringing the air in contact with its surface; and the same position operated to diminish the contact of the hot smoke on the pipe; rising in an uninterrupted column, a great part of its interior heat produced no effect, and elbows on the pipe to invert its internal arrangement, were inadmissible on account of the accumulation of soot which they occasioned—but their effect might have been attained by a throttle or turning valve in each pipe, which could have been adjusted to bring the smoke flowing past them nearer to the surface of the pipe at pleasure.

A pipe 6 inches in diameter and 27 feet high, with a surrounding space of 2 inches, was sufficient, when the windows were air-tight, to maintain three rooms containing 4063 cubic feet at 58°, when the external air was 29°. This heat previously passed through the pipe without performing any service whatever; and, had the smoke-pipe been throttled, the same surface would have warmed a much greater cubical area.

Mr. Beaumont's stove is shown in Fig. CCI., and Fig. CCII. A foundation of bricks, *a*, is laid two courses high and 25 inches square, leaving an ash-hole 6½ inches wide. Upon this are laid two plates of cast iron, *c*, each 9 inches wide, 25 inches long, and an inch thick, with a rabbet ½ inch wide in their inner and upper edge, to receive a counter rabbet in the middle plate of iron, *d*, of the same thickness, 7½ inches wide and 20 inches long, which draws out by a ring fixed in it, when it is necessary to empty the ashes into the ash-hole. An aperture, *e*, 12 inches square, is left in the drum for the smoke-flue. The drum being placed

FIG. CCI.

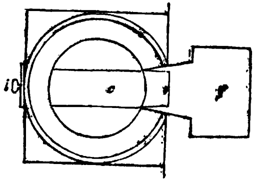
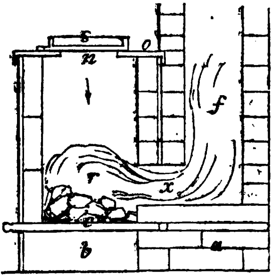


FIG. CCII.



on the plates, the smoke aperture, *e*, is reduced to 6 inches in width by 4½ inches in height, by a collar formed of Stourbridge bricks or Welsh lumps, 12 inches by 9 inches, 3 inches thick, set in Stourbridge clay; and the rest of the inside is lined with 3 courses of Stourbridge bricks set on end and on edge, and bedded in Stourbridge clay. The drum is covered with a circular plate of cast iron having a downward lip round the edge to receive the upper edge of the drum. In the middle of this cover, *n*, there is a hole 7 inches in diameter for the admission of fuel, and this is covered with a lid which moves on a pivot to regulate the admission of the air. It is seldom necessary to leave it open more than an inch for that purpose. The lid itself is cast with a rim projecting about an inch, that it may contain a little water, for a moderate evaporation preserves the salubrity of air artificially heated. "When a fire is wanted, a few coals are first thrown in, then some sticks and paper are placed over it, and some cinders or coke with a few bits of coal are immediately put on the wood, taking care to give the fuel a slope in such manner as to leave the opening to the smoke-flue pretty clear; the aperture at top is then *nearly closed.* After the fire has been lighted, the first effect is for the smoke to ascend towards the aperture over it, but this is opposed to the downward current produced through the small aperture to supply the vacuum caused by the fire. The smoke is seen curling about in its endeavour to ascend, but it is driven back by the downward current which now sets into the smoke aperture, *e;* and carrying with it the gaseous products of the combustion into the flue, *s,* the fire continues to burn clear and bright. At night the aperture is closed and the fire goes out. All the fuel is consumed—a perfect combustion has been produced—no soot is produced to choke the flues, nor half-burned coals and cinders remain to fill the ash-pit; a red ash is all that remains."

The management of the stove is easy; all that is required being to push the slide, *d,* home before the fire is lighted, and to let the fire burn bright before much fuel be put on, and to keep the smoke-vent, *e,* from being choked up by overloading it with fuel. A small scraper, something like a chimney-sweeper's, is the only implement required to clear out the smoke-flue; with its handle it should not exceed 15 inches in length, that a violent servant may not injure the brickwork.

In noticing some modes of heating which had been tried in an office, before this stove was constructed, Mr. Beaumont says, that although the air was sometimes too hot, still the clerks always complained of cold feet. They had mats given them to stand on, and they frequently left their desks to get a warm at the hot air vents or steam-case, but still their feet were cold; and it being considered that this could only be removed by causing the heat to rise through the paved floor itself, a flue was accordingly constructed under the pavement—the paving stones themselves forming the roof of it. The flue is a foot square, and begins on one side of the office, travels under the pavement, along that side, across the top, and down the other side, where it enters an upright flue in the party wall. The hot vapour from the stove enters this flue and passes under the feet of the clerks, which it keeps comfortably warm; the heat, being filtered as it were through stone, rises in the utmost purity. There is no longer a difficulty in keeping up the heat to a required pitch; the warmth is so considerable from a mere handful of fire, that the difficulty has been to keep it low enough without putting the fire out. An office and principal staircase are kept warm at an annual expense of thirty shillings, or about three-pence a day for the cold season; a similar degree of heat from another apparatus cost eighteen pounds annually. Persons coming in from the open air have complained of our keeping large fires, and when they have been shown that the fire was a small one burning without fierceness, and which might be contained in the crown of a hat, they have denied their belief to the fact, and insisted that the warmth which they felt must have been procured from some other source. It really does appear like magic, says Mr. Beaumont, but the case proves the fact of one part only of the heat from the previous apparatus going to the place to be heated, and that eleven parts went up the chimney and was wasted at the house-top.*

A sketch of the stoves invented by Mr. Bernhardt is shown in Fig. CCIII. and Fig. CCIV.: *a*, the furnace; *b*, 16 iron pipes, nine inches in diameter and 18 feet long, through which the smoke from the stove moves in an ascending direction to the pipes, *c*, *c*, which convey it to the flue. These heating pipes are enclosed in a chamber, *x*, through the floor of which cold air is admitted from the tunnel, *t*, which, coming into contact with the series of heated pipes, *b*, as it rises into the chamber, is heated, and then conducted through the openings, *i*, *i*, in its roof, into the pipes or tunnels which convey it to the rooms where warmth is required. The smoke in circulating through these pipes deposits nearly the whole of its soot; and as the necessity of removing it is of frequent recurrence, it is cleared by opening the small doors, *h*, *h*, made on the outside of the wall.

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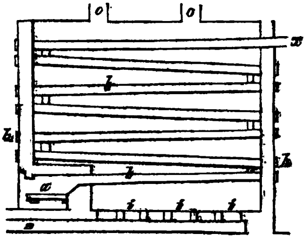
* Hints for Preventing Damage by Fire, p. 52.

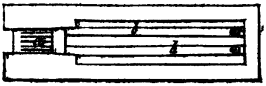
FIG. CCIII.



The temperature of the stream of air issuing from the apertures did not rise higher than 150°.

The pipes forming this stove had 472 square feet of surface; and three other stoves were placed in the same mansion, which does not perhaps contain a cubic area of 150,000 feet; so that as much pipe surface was used to warm it, "as was sufficient, had it been judiciously employed, to heat the vast area of St. Paul's or Westminster Abbey."*

FIG. CCIV.



* Arch. Mag. vol. v. p. 34.

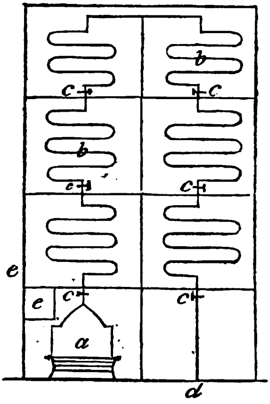
ESSAY XIV.

There is something pleasant in the recollection of Sir Hugh Platt, several of whose contributions to fireside comfort have been already described. That truly affectionate and diligent lover of plants held a correspondence with the favourers of agriculture and gardening throughout England; and although a lawyer, such, says Weston, was his justice and modesty, that he always named the author of every discovery communicated to him. The excellent knight, having nowhere mentioned that he received the hint from another, is to be considered the first who pointed out steam as a medium for heating the air of a room.

"For the keeping," says Sir Hugh, "of any flowers or plants abroad, as also of those seeds sowed within doors, or other pots of flowers or dwarf trees, in a temperate heat, with small charge you may perform the same, by hanging a cover of tin or other metall over the vessel wherein you boil your beefe or drive your buck, which having a pipe in the top, and being made in the fashion of a funnel, may be conveyed into what place of your orchard or garden you shall think meete; which room if it were so made as that at your pleasure it may become either close or open, you may keep it in the nature of a stove in the night season, or in any other cold weather, and in the summer weather you may use the benefit of the sun beames to comfort and cherish your plants and seeds; and this way, if I bee not deceived, you may have both oranges, lemons, pomegranates, yea, peradventure, coloquintida, and pepper trees and such like. The sides of this room, if you think goode, may bee plaistered, and the top thereof may be covered with some strained canvas to take away at your pleasure. Quære, If it be the best to let the pipe of lead to breathe out at the end only, or else at divers small vents which may be made in that part of the pipe which passeth along the stove. I fear that this is but a meer conceit, because the steam of water will not extend far; but if the cover to your pot bee of metall, and made so close that no air can breathe out saving at the pipe which is soldered or well closed in some part of the cover, then it seemeth probable that this cover may be put on after the pot is scummed."*

In 1745, Colonel William Cook improved on Sir Hugh's suggestion, and gave a diagram of an engine for heating all the rooms in a house from the kitchen fire. In Fig. CCV. "*a* is a copper with a still-head; *b*, a copper or lead pipe through which the steam from the head of boiling water heats. In its passing through the eight rooms, the pipe is fixed to the wall or side of the room; in the place of the chimney, *c*, are stopcocks by which the steam may be suffered to pass as fast or as slow as you please; *d*, vent for

FIG. CCV.



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* Garden of Eden, p. 19. Stuart. Anecdotes of Steam Engines, p. 36.

steam to pass out at; and *e*, cistern of water to replenish copper as it boils away."*

The Colonel's scheme was propounded as a saving, and was so far practicable, that there is no doubt, with a tithe of the coals wasted in the fireplace, he could have heated three times the number of rooms enumerated in his proposal. In 1755, it was suggested as a method for forcing fruits.†

The first practical application of these hints was made by the celebrated improver of the steam-engine. In the winter of 1784-5, Mr. Watt used it for warming the room in which he commonly wrote. The apartment was 18 feet long, 14 wide, and 8½ feet high. The apparatus was a box or heater made of two side plates of tinned iron, about 3½ feet long by 2½ feet wide, kept at the distance of an inch asunder by stays, and joined round the edges by other tin plates. This box was placed on its edge near the floor of the room, and furnished with a cock to let out the air, and a pipe proceeding from its lower edge to a boiler in an under apartment to supply steam and return the water of condensation. The effect produced by this apparatus was less than Mr. Watt expected, but the failure could not be explained until Leslie made his experiments on the heat transmitted by polished surfaces. Soon after this, Mr. Boulton heated a room in his house by steam; and about 1789, a bath also, which he continued to use for twenty four years.‡

Mr. Wakefield, at Liverpool, with a knowledge of what had been done elsewhere, in 1788, made the first attempt at heating a hot-house by steam.§ And in 1791, Mr. Hoyle, of Halifax, had a patent for heating by steam-filled pipes, in which the vapour was carried to the highest elevation, and thence by a gentle declivity was made to deposit the condensed steam or water into the supply cistern of the boiler. He observed that the heat produced would be in proportion to the quantity of pipe in the space to be warmed.* He fixed his apparatus in some cloth manufactories at Halifax, and at Bradley, and in a house near London. In the latter, the copper pipes often getting out of order, and the effect being found too small, Mr. Green, who had a patent in 1793 for a different method, was called in to alter it; but his improvement greatly increasing the radical defect, it was removed.

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* Phil. Trans., 1745, p. 870.

† Gentleman's Mag., 1755.

‡ Treatise on Economy of Fuel, p. xiii.

§ Loudon, Remarks on Construction of Hot-houses, p. 53.

Mr. Green's plan consisted in enclosing a hollow vessel or worm-pipe in a boiler containing hot water or steam, by which a too great heat was prevented being given to the air, which by this means "was preserved from being burned, and was always fit for respiration."

He also attached pipes to a steam boiler, and enclosed them in other pipes. Into the interval he admitted the external air, which he conveyed to the place, where heat was wanted; or he inserted the pipe containing the air to be heated, in the inside of the larger pipe which he filled with steam.† Both were good practical methods. Mr. Green preferred the first. He had several opportunities of exhibiting the merits of his scheme; but although very ingenious, he was far from being skilful. In a mansion on Wimbledon Common, he fixed his encased pipe along the ceiling of the basement floor, with an inclination of 2 inches in 60 feet. The inner steam-pipe was 3 inches in diameter, the outer air pipe was 9 inches, both were of copper. The lower end of the casing pipe was left open for the cold air to enter; the other end was joined to a pipe 4 inches in diameter, with 3 horizontal elbows, that rose about 12 inches, where it opened into the first of a suite of rooms that were to be heated.

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* Rep. of Arts, vol. i. p. 304.

† Rep. of Arts, vol. i. p. 304.

It was hoped the air would enter at one end in great quantity, and flow out through the small pipe at the other into the rooms. Mr. Green was unable to discover the cause of its feeble effect. A pipe was conducted from the boiler into a pipe enclosed in another, which was placed on the second story to ventilate a room beneath according to Sir G. O. Paul's plan. This acted with comparative energy.* The entire apparatus remained in occasional use for 16 years, and after several times the first cost had been expended in tinkering, it was finally removed. A library heated for Lord Lansdowne was a failure also. In 1794, Mr. Watt assisted the noble proprietor to improve this apparatus, but from some defects in the joints of the copper pipes, it occasioned so much trouble that its use was given up.† Mr. Green was more successful in heating a vinery and plant-house in a merchant's villa at Hammersmith, where it gave great satisfaction for several years, when it was taken down and sold by Mr. Morton's creditors.

Steam heat appears to have early become a favourite with gardeners, from a comparison of its advantages over the heat from flues, as then practised. At Knowsley Hall, in 1793, Mr. Butler, gardener to the Earl of Derby, introduced the hot vapour *under* the bark in melon and pine pits, and allowed it to escape in the dung among the pots. Mr. Mawer, a Lancashire man who had settled near Edinburgh, and who had seen Mr. Wakefield's and Mr. Butler's experiments, adopted it in an extensive range of hot-houses at Dalry in 1793. There were seven houses, pineries, peach-houses, and vineries, constructed with flues and furnaces in the usual manner, but over the furnace of each house was placed a cast-iron boiler 3 feet in diameter, and 14 inches deep, covered with a flat stone in which was a valve of considerable weight;

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* See p. 76, Fig. LXXVIII.

† Buchanan. Treatise on Economy of Fuel.

one side of this boiler, immediately under the cover, had a projecting nozzle, and to this was cemented an earthenware pipe which conveyed the steam to the house. These pipes, when united, formed only one length from one end of the house to the other, either in the bark-pits or in the passages, and were so raised at the further end as to return all the condensed water to the boiler. At every 6 or 7 feet was a bunghole or opening in the pipe for the purpose of admitting steam to the house, and these pipes, when not wanted for this purpose, were stopped with moss, when the steam escaped by the valve. A supply cistern, in which the water was constantly kept at one level by a ball cock, was connected by a pipe with the boiler. The steam here could never be of a very high temperature, and the chief advantage derived from it was as hot vapour introduced into the body of the house, which soon elevated its temperature; but as the steam declined, it fell to the usual degree kept up by common flues. Its effect was to promote a very rapid and luxuriant growth; and totally to prevent the appearance of insects. The apparatus was used for seven years, but after Mr. Mawer's death it was allowed to fall into ruin. Various gardeners in East and West Lothian adopted the same system, chiefly as affording a wholesome dew; and some merely placed a common broth pot over the furnace, allowing the vapour to enter the house through a cavity in the masonry.*

In the winter of 1795-6, Mr. Bolton erected an apparatus in his friend Dr. Withering's library at Birmingham, which in point of heating answered perfectly; but the pipes being made of copper and soft-soldered in some places, the smell of the solder was rather unpleasant to the doctor, who was then in an infirm state of health with diseased lungs, and Mr.

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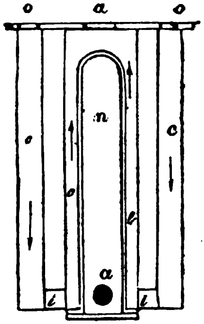
* View of the Agriculture of Mid-Lothian, App. p. 31.

Bolton removed the apparatus to Soho, in order to erect it in his own house, in which he intended to heat every room by steam; but the purpose was afterwards abandoned. The subject of steam-heating underwent, however, says Mr. Buchanan, frequent discussions; and the different methods of effecting it were amply considered by Messrs. Boulton and Watt, who made no secret either of calculations of surface or modes of applying them.* In 1799, Mr. Niel Snodgrass introduced the method of heating by steam in a cotton manufactory on the banks of the Spey.†

About 1800, Mr. Lee, of Manchester, under the direction of Messrs. Boulton and Watt, erected a heating apparatus of cast-iron pipes, which served also as supports to the floor, and was, in point of materials used, and construction, the earliest of its kind. He subsequently heated his house by steam, and the staircase, hall, and passages were warmed by an ingenious apparatus shown in Fig. CCVI., placed in the underground story.

The vertical cast-iron cylinder, *a*, is surrounded by a casing of brickwork leaving a space, *e e*, of 2½ inches all round, and having openings, *i*, below, to admit the air. This casing is surrounded at the distance of 3 or 4 inches with another wall, which forms what may be called the well, *c*. The coldest air, being the heaviest, falls to the bottom of the well, *c*, and entering by the holes, *i*, into the space, *e*, comes in contact with the cylinder, *a*, where being heated and becoming specifically lighter, it ascends. There is a valve to re-

FIG. CCVI.



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* Treatise on Fuel, p. xv.

† Trans. Soc. of Arts, vol. xxiv. p. 198.

gulate the admission of steam into the cylinder, and a small pipe to allow the air to be expelled, when the steam is entering, that are not seen in the figure, and another small pipe to withdraw the water of condensation. Another valve is placed on the top of the brickwork at *a*, to regulate the transmission of the heated air. When this apparatus was in action, the staircase soon became so warm that it was necessary to shut either the valve admitting the steam, or the air valve at *a*.

Count Rumford assisted in designing an apparatus to heat a part of the Royal Institution, where he introduced thin copper drums attached to the pipes to allow of their alternate expansion and contraction without opening the joints. With the exception of another contrivance to answer the same end, but which has not found its way into practice, there has been no improvement made in the details or arrangement of this variety of steam-apparatus since the erection of that in Mr. Lee's manufactory. The extension of the system was much promoted by Mr. Buchanan at Glasgow, particularly by a pamphlet that he printed on steam-heating in 1807, and which he enlarged a few years afterwards with descriptions of apparatus. Nothing of value to a practical man, or in which he should have the least confidence, has since been printed. In workmanship, modern apparatus is not equal to that erected by Boulton and Watt forty years ago. In this as in other branches of mechanical engineering, the competition or minimum system, that at all times grinds if it should fail to ruin the workman, is most certain in its effect of debasing the quality of his work.

Where this method of heating is introduced, the steam is often drawn from a boiler which supplies a steam-engine, and the additional size given to the evaporating vessel is 1 cubic foot, for every 2000 cubic feet of space to be heated to 70° or 80°. A boiler equal to supply steam to an engine of 1 horse power, is sufficient in size for heating 50,000 cubic feet of space. When a distinct apparatus is to be constructed, a more exact estimate is, however, attempted.

With a careful management of the fire under a small boiler, it is found that about 14 lbs. of Newcastle coal are required, to convert 1 cubic foot of water at the temperature of 50°, into 1800 cubic feet of steam at 216°; and about 12 lbs. to raise the same quantity from water at 212°.

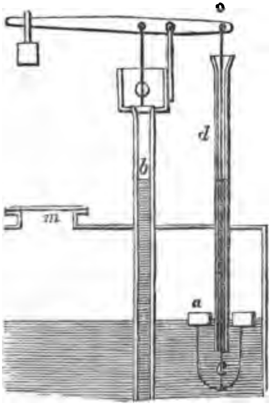
To burn 14 lbs. of coal an hour, will require an area of about 1 foot square of fire-grate, in which there is from 30 to 34 square inches of air opening between the bars; and to evaporate this quantity, with a moderate draught in the flue, from 7 to 10 feet square of boiler surface is to be exposed to the direct action of the fire. In general, it is found most advantageous to make the area of the fire-grate and boiler surface, approach the most ample dimension; and where the fire surface is diminished, to increase the area of the fire-grate. When coke is burned, a square foot of grating, with an air space of 27 inches, and 9 square feet of boiler fire surface, is found a good proportion. In small boilers, the surface exposed to the direct action of the fire, may be made to envelope nearly the whole surface in contact with the water. Plane or slightly curved surfaces, such as those forming the bottom of the wagon-shaped boiler, seem more favourable for the reception of radiant heat, than those of cylindrical and globular vessels; but in practice, little difference in effect is observed among them.

Small boilers are often formed with flues, conducting the hot smoke round them, before it enters the chimney. That portion of boiler surface exposed to to the smoke can seldom, in favourable circumstances, be estimated to have an effect equal to ¼ of the sam extent of fire surface; in common cases, it is much less. Count Rumford found the evaporation nearly as great, when the circulation of the smoke in the flue was totally obstructed, as when it was rapid; and side flues he considered in most cases, useful only in preventing the radiation of heat from the boiler. They are less effective in small, than in large boilers. Internal flues are seldom introduced into the former; their economy of heat is doubtful, but their effect certain in increasing the chances of accidents and hastening the wear of the boiler. The perpendicular smoke-flue after it leaves the boiler, may have an area double that of the sum of the air spaces between the bars, and be fitted with a regulating damper. The area for the smoke, when the furnace is in action, will seldom be more than the sum of the air spaces. Where it can be had, a deep ash-pit is very desirable; but whether deep or shallow, it should in all cases be carefully enclosed by a door, as nearly air-tight as neat workmanship in fitting will make it. The air-valve, which should extend nearly the whole width of the door, or rather the width of the air spaces, should be formed to have an area when fully open equal to the sum of the spaces between the grate bars, and placed as low down, or as near the hearth, as possible. The furnace door also should be carefully fitted with a similar valved opening to that in the ash-pit door.

Burning the smoke, to save its heat and prevent its nuisance, has long been a favourite project with boiler-setters; and many clever contrivances have been tried for attaining the desired end, which the patriotic inventors are bound both by their duty to society and to their own interest to press on public attention, and to exhibit experimental proof of their efficacy on their own furnaces; but less ingenious or skilful persons may, without presumption or much loss, reject them all. In common hands, like those in which the management of steam-heating apparatus must be placed, the common furnace will be less likely to get out of order, and it will create very little smoke, and produce as much heat as many of the improved fire-places, provided the grate bars bear a proper proportion to the surface of the boiler, and that to the mass of water, and a *thin* fire be kept, frequently fed with small pieces of coal sprinkled thinly and evenly over its surface, and the quantity of air required by the chemical constitution of the fuel be admitted to the fire-place, by an adjustment of the air-valve in the ash-pit door.

The loaded safety-valve commonly placed on the boiler, may in general be omitted. The float, *a*, of the feed-pipe, *b*, is attached to a rod, *c*, enclosed in an iron pipe, *d*, open to the boiler, and containing water, which has the same head as that in the feed-pipe, and forms a steam-tight joint, and a safety-valve also, should the steam rise above the temperature due to the head of water in the upper pipe; and the same mechanism renders unnecessary both the common safety-valve opening inwards in case of a sudden condensation of steam in the boiler and the gauge-cocks; *m*, a man-hole for cleaning out the boiler. Some other

FIG. CCVII.



contrivances occasionally introduced, are not essential.

With all the care that can be taken, much heat will unavoidably be lost from the exposed surfaces of the boiler and furnace. Where practicable, the boiler should be wholly enclosed with brick work, built hollow, and the spaces filled with some imperfectly-conducting material; or it should be cased with a wrought iron jacket, and the space between filled with clay or charcoal; or the exposed surfaces should be covered with several layers of felt: and it is a good practice, where otherwise convenient, to enclose the boiler and furnace within a small chamber, with its fire-door only on the outside. The same care should be taken to prevent the dissipation of heat and access of moisture from those portions of pipe which are not placed in the spaces to be heated. Mr. Buchanan recommends them to be enclosed in a tin-plate pipe, with a space of 1 inch between the outer and inner pipe, or to wrap the steam-pipe round with a considerable thickness of straw rope, and coat them with fine plaster lime, washed over after it is dry with lime-water, in order to fill up any little cracks which may appear.* A covering, of three thicknesses of felt in situations where no moisture is apprehended, may be used with advantage.

At the introduction of steam heating, the pipes we have seen were of copper and tin plate. Copper tubes, besides being expensive, are objectionable on other accounts. In cases where clumsy cast iron pipes are eye-sores, arrange them as you will, tin-plate pipes of small diameter might be introduced with propriety. They are sufficiently strong. Mr. Milne subjected some pipe, $\frac{1}{18}$ inch thick, which had been drawn on a mandril, to the pressure of a thousand feet of water without injury.* Their soldered joints are quickly made and repaired, are strong and very neat.

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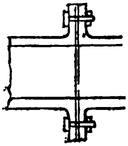
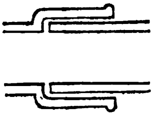
* Essays, p. 237.

Cast iron pipes are connected in various ways. The flange-joint, Fig. CCVIII. is made by interposing

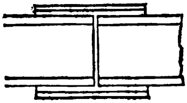
CCVIII.



CCVIX.



CCX.



some compact elastic substance, such as pasteboard, rope, yarn, or felt, soaked in a thick mixture of white lead and drying oil, between the flanges or projecting rims on the ends of the pipes, and then bringing them by screws firmly together so as to be steam-tight. This is the usual joint, but it is very unsightly and inadmissible for pipes placed in many situations.

The spigot and faucet, or socket-joint, Fig. CCIX. is much neater. It has been objected to from its supposed tendency to burst the faucets, in consequence of the expansion of the spigot, through too great a space being filled very hard with cement. The remedy is obvious. When carefully made it is not so liable to leak as a flange-joint, and when the cement dries the joint is as strong as the pipe itself. The faucet or socket is cast with a bead, to prevent its giving way when the joint is caulked. In some cases the spigot has a slight additional thickness given to it also.

The thimble-joint, Fig. CCX. is also a strong as well as a neat connection. If it breaks it is easily renewed, and one pipe may be taken out and replaced without disturbing the others. The thimble has been recommended to be made of thin wrought iron, leaving but a very small space for the cement, that the expansion may be equalized, and the risk of an unsound joint avoided. The saddle-joint, is composed of two pieces, forming a thimble, which are embraced by two hoops, the ends of which are secured and tightened by screws. This is a convenient joining, where a branch has to be made from the main pipe. The branch ought, however, always to be cast upon the main with its proper flange or faucet. When the pipes are vertical, the ends are ground to fit each other, as in Fig. CCXI., and the iron cement being placed between them, the weight is sufficient to unite the joint; where the exterior of the pipes must be flush at the joint, the projection is made inside the pipe.*

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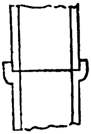
* Brewster's Journal, July, 1821.

FIG. CCXI.



In small wrought iron pipes used in some hot water apparatus, the joint is formed by placing the ends of the tubes within a socket, forming a right and left hand-screw; the edge of the one pipe being flattened and the other sharpened, they are screwed so tight that the edge of the one is indented in the flattened surface of the other.

The wrought iron pipes of small diameter that are occasionally used as branch pipes, or to carry off the

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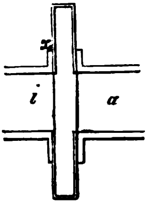
* To make iron cement, 40 parts by weight of iron borings are to be added to 1 part of sal ammoniac, and ½ part of flowers of sulphur, well mixed together and beaten up like pully.

Much sulphur renders the composition brittle. When a considerable time can be allowed for the cement to dry in the joint, before steam is admitted into the pipe a smaller proportion of sulphur may be used.—*Buchanan*, *Essay*, p. 177.

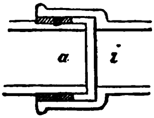
Different proportions are given by Mr. Peckstone. The iron burnings or borings are to be pounded in a mortar, until they are fine enough to pass through a fine sieve. Then with 1 lb. of these borings so prepared, mix 2 ounces of sal ammoniac in powder, and 1 ounce of flowers of sulphur by rubbing them well together in a mortar; afterwards keep the mixture dry till it is wanted for use. When it is to be used for every part by measure, take 20 parts of iron borings, prepared as described, and mix the whole well together in a mortar, and bring the compound to a proper consistence by pouring water gently over it as it is mixing. It is then to be applied between the flanches by a blunted caulking-iron, where it is to be well set up, and after the joints are screwed up very tight the loose cement is to be scraped off.—*Practical Treatise on Gas Lighting*, p. 340, water of condensation, are screwed into the cast iron pipe; by whatever methods the joints are made, the space between the joined ends should be as small as possible to prevent the lodgment of water in the lower part.

In a series of metal pipes an allowance has to be made for their expansion in length when heated. The thimble-joint, Fig. CCXII., is sometimes formed on a range of pipe to permit this elongation. The adjoining ends of the pipes, *a*, *i*, are turned true on the outside, and have a thimble, as in the common joint; a piece of tin, *c*, or inner thimble, is interposed and made to fit well to the turned parts of the pipes which work backwards and forwards, like a piston in a cylinder, as the pipes expand or contract. In a range of pipes, 120 feet in length, it permitted a movement of ¾ of an inch. A similar expansion-joint, applied to a spigot and faucet connection, shown in Fig. CCXIII., was found to be durable and effective.

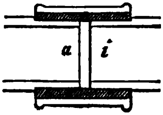
CCXIV.



CCXIII.



CCXII.



Lead, as a substitute for tin or iron cement in joints, is an improper material. By alternate expansion and contraction it suffers a permanent change of form, and joints made with it soon get loose. Count Rumford's expansion drum, *a*, Fig. CCXIV., is made of thin copper; as the pipes, *a*, *i*, elongate, they press the thin sides, *x*, of the drum inwards, and as they cool they draw the sides out: it is now seldom used. Where the range is placed horizontally, the pipes, *a*, should be supported on rollers, *c*, Fig. CCXV., kept carefully detached from the building, in order to have full liberty of expanding; and when placed vertically, they should never form part of the construction, or support any part of the building.

FIG. CCXV.

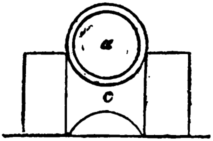
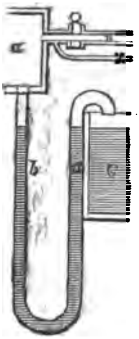


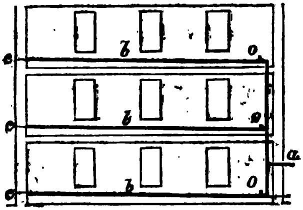
FIG. CCXVI.



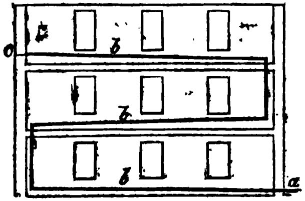
The water formed by the condensation of the steam is always carefully removed from the pipes, by giving them a considerable inclination to the horizon, as its accumulation prevents their acquiring a uniform temperature, and the apparatus is endangered from unequal expansion. In general it should flow in the same direction with the steam, and in order to save its heat, be again conducted into the boiler. Where water is scarce, or of a quality which speedily encrusts the boiler, it is then most desirable to supply the feeding apparatus with the distilled fluid. A common method of removing the condensed water is by a syphon, *a*, placed at the lowest extremity of the range, *b*, and of a height equal to the pressure of the steam in the pipes in Fig. CCXVI., *a*, as the steam-pipe to the syphon, *c*, the supply cistern for the boiler is. Where the necessary depth cannot be had conveniently, the water may flow into a cistern provided with a ball and cock to open and shut the pipe, like that placed in a water cistern; but this being liable to get out of order, the syphon is the preferable apparatus.

While the pipes are filling with steam, the air they contain is allowed to escape through a valve or stop-cock, which is closed when the operation is completed. Where the circulation is continuous, the air-cock, *e*, Fig. CCXVII., is usually placed at the extremity of the steam-pipe; but where it is interrupted, a valve is required at the extremity of each branch pipe.

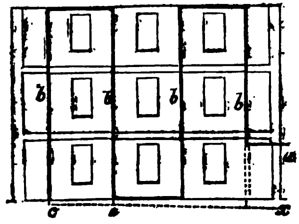
FIG. CCXVII.



CCXVIII.



CCXIX.



In practice, it is found that the circulation is improved if a minute quantity of steam is suffered to escape constantly through a very small hole, or by a pipe, it prevents the retardation which is sometimes occasioned by an accumulation of incondensable air in the pipe, and the steam may be allowed to mix with the air of the room, which will improve its quality and save the heat; or it may be allowed to flow from the air-valve either into the chimney or open air.

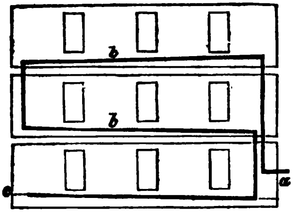
A common method

of arranging heating-pipes is shown in Fig. CCXVII. The pipe, *a*, from the boiler, rises to the upper story, from which a pipe, *b*, branches horizontally to each floor, and by means of a stop-cock, *o*, the steam may be turned into or from any particular floor at pleasure. The water of condensation produced in each pipe falls towards the rising pipe, and is conducted, when the level of the lower pipe permits, into the boiler. But where the boiler cannot be placed under the level of the lowest floor, the steam-pipe is carried near its ceiling: but it is better to place the heating surface in the best position, than to save a little heat from the condensed water; and, therefore, the arrangement shown in the figure is preferable where the pipe in the basement-story descends from the boiler to the floor, and the water of condensation falls into a reservoir, from which it is pumped into the feeding-cistern. A pipe and cock, *c*, is placed at the end of each horizontal steam-pipe, to let the air blow off when it is filling with steam.

In Fig. CCXVIII., steam from the connecting-pipe, *a*, enters the heating pipe, *b*, placed near the floor, and which is carried with a gentle inclination to the opposite end of the room, where it rises into the next story, and returns along its floor to the opposite end, where it rises into the third floor, and proceeds as before. In this, as in the preceding arrangement, the water of condensation runs contrary to the current of the steam; and is removed by a syphon placed at *a*. The air-cock is fixed at the highest point of the range, *c*.

Vertical heating pipes, *b*, as in Fig. CCXIX, have the least favourable position; and if the room be lofty, much of the heat will be lost, unless the ventilation proceed by a descending current.

In Fig. CCXX., the steam rises in the main pipe, FIG. CCXX.



a, to the third story, and then descends to the second and ground floor.

In manufactories and large rooms, the steam-pipes are sometimes carried along the centre of the room, to diffuse their heat more equally: but in other cases they are placed a few inches from the side wall; and in a room 42 feet wide and 150 feet long, in which they were thus placed, the temperature was found sufficiently uniform, and the pipe more out of the way.

Where the appearance of pipes is objectionable, the necessary quantity of heated surface may be had from forms corresponding with the other ornaments of the apartment in any style of architectural decoration. As an example, the steam may be conducted from the boiler by a pipe, that runs under the floor into a series of vases, one of which is placed in the hearth recess of each room, with a small pipe and cock, to allow the air to escape when they are filling. The Marquis de Chabannes enclosed a series of pipes, open at both ends, in an ornamental cylinder, one or more of which he placed in each apartment. In another case, the steam-pipe had the appearance of the skirting; and at an inn, it was carried along the ceiling, moulded like a cornice.

The following table, collected from cases given by Mr. Buchanan and others, exhibits the practical effect of a given surface of steam pipe in keeping a certain cubic area of building at a certain temperature, when the external air was *under* the *freezing point* of water:—

Description.	Cubic feet of space heated by one square foot of pipe.	Temperature of internal air.
A chapel; cast iron pipes . .	400	60°
A meeting-house; cast iron pipes	370	
A church; massive walls and stone pillars, inside stone, no plastering or wainscot, except for seats, cast iron pipes .	270	48°
Dining-room; cast iron pipes .	180	64°
Ditto, containing 8,400 cubic ft. of space, 15 ft. from floor to ceiling	209	62°
Public-room; cast iron pipes .	306	54°
Cotton mill; tin-plate pipes, not painted	200	
Six cotton-mills, each containing on an average 205,006 cubic feet of space, cast iron pipes .	175	80°
Staircase, average of five, with lantern lights . . .	163	56°
Average of four others with window in wall . . .	174	56°
Rooms in an inn . . .	200	
Counting-house, lighted from the ceiling	256	61°
Average of three do. lighted from side	243	64°
Average of seven rooms in a public building, heated by an ornamental cast iron vase in each, ¾ inch thick; greatest effect.	140	56°
One of the rooms, fitted with a double window, could be kept at		64°
Calico-printers' work-room .	90	80°
Ditto. press-room .	144	
Forcing-house	30	80°
Drying-house; cast iron pipe .	80	100°

Description.	Cubic feet of space heated by one square foot of pipe.	Temperature of internal air.
Drying-house; tin-plate pipes .	40	90°
Drying-house, walls and windows defective . . .	23	90°
Forcing-house, glass very defective	25	73°
Printing-office; 4 floors average	266·5	68°

The quantity of steam-heated surface required to produce a certain average temperature, may be readily approximated by dividing the cubic contents in feet of the building to be heated by the number placed in the first column opposite the description of a similar building. Thus, for a factory, containing 100,000 feet of space, this number divided by 175 in the table will give 574·2, which is the number of square feet of pipe surface that will keep it at a temperature of 80° in the coldest weather. If the cubic area of a dining-room be 5,000 feet, this divided by 140, one of the numbers in the table, will give about 35·7 square feet of steam-pipe surface required to warm it to a summer heat, with the air outside at the freezing point. These it is obvious, although rough, are safe practical estimates, that may be applied and depended on in numerous analogous cases.

The required quantity of steam-pipe is sometimes estimated in another way. If, for example, 200 cubic feet of air are to be supplied in a minute, to a room which is to be kept at a temperature of 60°, when the external air is at the freezing point, and the average heat of the surface of the steam-pipe is to be 200°, then, if the difference between the temperature the room is to have and the external air be multiplied by the number of cubic feet of air required per minute, and the product divided by 2·1 times the difference between 200 and the temperature of the room, the quotient will give the number of square feet of heating surface required,* thus :—

$$(60-32) \times 200 = 5600 \div 2{\cdot}1\ (200-60^\circ) = 19$$

which is the square feet of heating surface to be used.

An estimate formed from the table, omits the consideration of any definite amount of ventilation: and formed from the rule above, omits any reference to the cubic space to be heated. For instance, a room containing the same number of persons, and windows, but of twice the cubic capacity, or one with double the superficial area of radiating wall, ceiling, and floor, would be supplied with the same quantity of pipe! The rough approximation to be had from the table will therefore be found a useful check on the still rougher guesses made by means of the rule.

In Dr. Arnott's method of finding the amount of heating surface, one of the omissions in Mr. Tredgold's rule is supplied, "To maintain," says the doctor, "in an ordinary apartment the agreeable and healthful temperature of 60°, there must be of surface of steam-pipe or other steam vessel heated to 200° (which is the average surface temperature of vessels filled with steam at 212°), about one foot square for every six feet of single glass window of usual thickness; as much for every 120 feet of wall, roof, and ceiling of ordinary material and thickness; and as much for every six cubic feet of hot air escaping per minute as ventilation, and replaced by cold air. A window with the usual accuracy of fitting is held to allow about eight feet of air to pass by it in a minute; and there should be for ventilation at least three feet of air a minute for each person in the room. According to this approximation, a room 16 feet square by 12 feet high, with two windows each 7 feet by 3, and with ventilation by them or otherwise, at the rate of 16 cubic feet a minute, would require 20 feet of pipe 4 inches diameter, or any other iron vessel having the same extent of surface.*

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* Tredgold. Principles, &c., p. 59, 1824.

If pipes 3 inches diameter externally are to be used, then the amount in square feet of heating surface multiplied by 1·09 will give the number of feet in length of 3-inch pipes required; or of 4-inch pipes, if multiplied by ·82; of 5-inch pipes by ·66; and 6-inch pipes by ·55. Thus, in the above example, 23·7 × 0·82 = 19·4, which will represent the number of feet of 4-inch pipe required to heat 200 cubic feet of air in a minute from the temperature of 30° to 60°.

The allowance made for the expansion of cast-iron pipes is in practice $\frac{1}{8}$ inch in 10 feet, or $\frac{1}{960}$ of their length. When heated from 32° to 212°, cast-iron expands $\frac{1}{900}$ of its length, bar-iron $\frac{1}{819}$, copper $\frac{1}{581}$, brass $\frac{1}{585}$, tin $\frac{1}{462}$, lead $\frac{1}{351}$, zinc $\frac{1}{338}$.

The size of the boiler is regulated by the capacity of the heating-pipes. As much space is left for the steam in the boiler as is equal to all the steam in the pipes; and the space for the water may be about one-eighth less. The water-line should always be kept above the highest part of the flue.

The quantity of coal used depends much on the management of the fire. With the usual attention of domestics 1 lb. of the common sort of coal will heat 83 cubic feet of water 1°, or from water at 50° it will raise about 122 cubic feet of steam at 216°. By greater care and some skill but on which those who pay for the fuel should rarely reckon, this effect may be increased a fourth. Therefore if the number of cubic feet of air warmed in an hour be divided by 3,000, and the quotient multiplied by ·012, this product multiplied by the number of degrees the air has been heated will give the pounds of coal used in an hour.

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* On warming and ventilating, p. 33.

Thus if 500 cubic feet of air in a minute, or 30,000 cubic feet an hour, be raised from 30° to 60°,

30,000 ÷ 3,000 = 10 × ·012 = ·12 × 30 = 3·6,

or little more than 3½ lbs. of coal an hour.

The height of the surface of the water in the feed-pipe for supplying the boiler when the temperature of the steam is

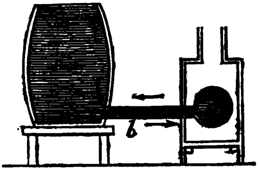
217° will be 3·9 feet
220° „ 6·2 „
225° „ 10·4 „
230° „ 15· „
235° „ 20·5 „

The temperature seldom exceeds 217°; and should not be carried beyond 230°, when the pressure will be about 6¾ lbs. to the square inch. The height of the feed-pipe gives the pressure in the syphon when the condensed water is removed by one.

ESSAY XV.

In the same treatise in which Sir Hugh Platt throws out the hint of heating a plant-house by steam, he suggests that hot water might be used to avoid the danger then run, in one of the processes of the manufacture of gunpowder. "To drie this substance without all danger of fire, you may cause," says Sir Hugh, "a vessel of lead, pewter, latten, or copper, to be made, having a double bottome, between which bottomes you may convey scalding water at a pipe, which water may be also heated at another roome, and then you may lay your powder upon the uppermost bottome till it be drie, and when the water beginneth to cool, you may let it out at a cock in the bottome of the vessel, and soe give passage for more scalding water by another cock."* And in another part he says, "a vessel may be made to brew or boil in, by making a fire under a brass boiler, *a*, Fig. CCXXI., and conveying the steam or water into a wooden tub or receptacle, *b*." Rudolph Glauber, also, proposed heating a brewer's vat, by a brass ball filled with water and placed in a fire, a pipe from which was carried into the vat. "A contrivance," says Hooke, "which if prosecuted,

FIG. CCXXI.



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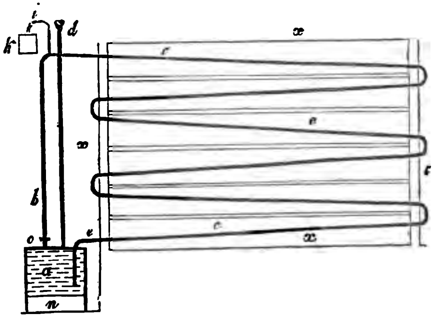
* Jewel House, p. 52.

might be very beneficial to those who require great quantities of hot water, by enabling them to use wooden casks instead of copper boilers."*

Sir Martin Triewald, a Swede, who lived for many years at Newcastle-on-Tyne, before he finally settled in his native country, about 1716, described a scheme for warming a green-house by hot water, instead of by fermenting vegetable substances. The water was boiled outside of the building, and then conducted by a pipe into a chamber formed under the plants.†

Prior to the French Revolution, an ingenious application of the same medium for diffusing heat was made by M. Bonnemain, in an apparatus to hatch chickens, to supply the Paris market.‡ In this water-stove, a transverse section of which is shown in Fig. CCXXII.; *a*, boiler, *n* or its furnace, furnished with an *expansion-rod* to regulate the opening and shutting of the ash-pit door; *d*, a pipe for supplying water to the boiler, and keeping the pipes always filled with water; *o*, stop-cock, for regulating

FIG. CCXXII.



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* Stuart on the Steam Engine, vol. i. p. 196.

† Ibid. vol. ii. p. 587.

‡ Ure. Arch. Mag: vol. v. p. 40.

the quantity of the ascending hot water; *b*, pipe of communication between the boiler and heating-pipes, *c*, which traverses the hatching-chamber, *x*, with a slope towards the boiler, into which it is inserted, and its lower end carried nearly to the bottom of the vessel. The air disengaged from the water by boiling, and which would accumulate in the tubes and obstruct the circulation of the hot water, escapes by the pipe, *i*, and the water that rises along with it from the tube falls into the receiver, *k*.

As the water in the boiler gets warm, and becomes specifically lighter, it rises upwards in the pipe, *b*, and its place is occupied by the colder and heavier water, which flows from the pipe, *c*, and enters the boiler at its lower extremity, *e*. A current is thus established from the boiler upwards, through the pipe, *b*, and then downwards, through the range of pipes, *c*, *c*, into the boiler, with a velocity depending on the difference between the temperature of the water in the boiler, and that in the descending or heating-pipe at its insertion into the boiler. By this means a very equable temperature was kept up in the series of compartments in which the eggs were placed to be hatched.

For many years after this period, M. Bonnemain was in the habit of describing his apparatus to others, and a few years later a good account of it, explained by figures, was given in a French publication.

About 1812, hot water was used at St. Petersburgh in the manner practised by Triewald; and shortly afterwards, in the same capital, by Count Zubow, in a similar but more roundabout method. The water made to occupy the space commonly filled by the fermenting substances, was heated by steam raised in a boiler placed on the outside of the conservatory.* It is not clear whether this was before or after Mr. Braithwaite, at Kendal, warmed his counting-house by a small rectangular boiler, having its furnace included in a rectangular cast iron case, which had the appearance of a chest placed against the wall. From the boiler a small pipe proceeded to the condenser, which was a copper vessel, 18 inches in diameter, placed under a double writing-desk. The condenser was formed on the plan of the improved cylindrical refrigeratories. A very small quantity of steam was allowed to escape at the top, which was however condensed against the lid, so that none of it escaped into the room. The steam gave out its heat to the water in the condenser; which was found, when once warmed, to retain the heat for many hours.*

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* Trans. of the Horticultural Society, vol. iii. p. 431.

The Marquis de Chabannes, in 1816, introduced M. Bonnemain's method into this country; and in drawing the public attention to the hot water system he claimed the merit of being its inventor. "The most perfect definition I can give of it," says the Marquis, "is by comparing a boiler to the human heart, and the effect of caloric on liquids to the circulation of blood in our veins. The fire is the power which gives motion to the water, as the admission of oxygen into our lungs causes the circulation of our blood. A pipe is placed at the top which may have any length or winding, but must finally return to the bottom of the boiler. The caloric which rises into the upper pipe, and communicates itself to the liquid in it, which loses that heat as it flows through the pores of the metal, or any reservoirs which may be placed in its passage for the purpose of extracting it, becomes gradually colder, and in that state pressing on the rarefied pipe which issues from the top of the boiler, re-enters at the bottom in proportion to what goes out above—thus causing a continual circulation; and the liquid coming in contact with the fire at a colder temperature, and besides with friction extracts a still greater portion of caloric."*

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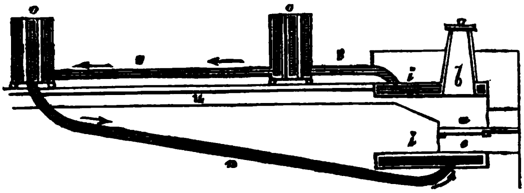
* Buchanan. Essays, &c. p. 292.

In reducing his speculation to practice, he proposed to fix a small boiler behind the kitchen fire, and connect it by two pipes with a cylinder, containing 20 or 30 or more small pipes, open at both ends, and surrounded with hot water. This cylinder he placed under the stairs. The rarefaction in the small open pipes produced a current of warm air in the staircase, and the water which was cooled in the cylinder falling into the boiler, forced the warmer water upwards into the cylinder with a continuous circulation.

Fig. CCXXIII. is a diagram of the way by which he proposed to heat a green-house: *a*, furnace, *c*, ash-pit, *i*, boiler, *u*, smoke flue, *s*, pipe traversing the space to be warmed, *n*, the return-pipe conveying the cooled water into the boiler, *b*, pyramid containing a supply of coal.† The operation of this is the same as that of the preceding apparatus. From its form a very large surface of the boiler is exposed to the action of the fire, and it contains a moderate quantity of water

FIG. CCXXIII.



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* On Conducting Air, p. 63.

† Ibid. pl. 13.

only, when compared with a boiler on the common construction. As the water is heated on the upper part of the boiler, it rises through the pipe, *s*, into the cylinders, *o*, and when cooled descends by its greater gravity through the pipe, *n*, into the bottom, *i*, of the boiler which forms the floor of the ash-pit, *e*. To increase the heating surface of the cylinders, *o*, which the Marquis called caloriferes, he filled them with small pipes open at both ends to the air of the conservatory, and which being surrounded with hot water, the air was heated in its passage through them.

Fig. CCXXIV. shows the manner in which he disposed his pipes to heat a dwelling-house, *a*, boiler, *c*, connecting-pipe, *i*, caloriferes, one or more of which were placed in each room according to its size, and connected by ascending and descending pipes, *n*, and the return-pipe that is inserted into the lower part of the boiler:—*u*, an expansion tube, and *s*, air pipes. The circulation proceeds upward from *a*, through the pipe, *c*, into the caloriferes, *i*, and at the bottom of the expansion-pipe, *u*, proceeds with a slight declination towards *s*, and thence descends to the boiler.

FIG. CCXXIV.

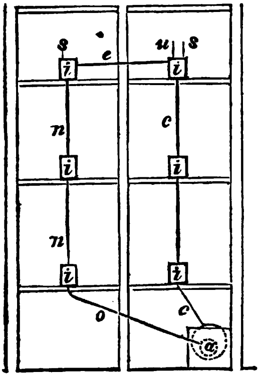
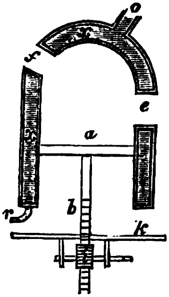


Fig. CCXXV. is a cylindrical boiler, designed by the Marquis, in which *k* is the ash-pit, *a*, fire-grate, which is moveable upwards or downwards by means of a rack, *b*, which goes through the ash-pit, and is moved by a pinion, *i*, that has a crank and handle

FIG. CCXXV.



on its axis: *o*, ascending circulating-pipe, *f*, smoke-flue, *e*, fire-door, and *x* the return-pipe. In many cases this would be an useful mechanism in conjunction with the air-valve.

Although it is evident, from hese examples, that the Marquis had a clear notion of the mode of action of his apparatus; yet being ignorant of some practical niceties of construction and arrangement, on which its effect often depends, but which could perhaps only have been acquired by experience, he did not succeed in establishing a popular reputation for his system.

Since his time, warming by hot water has been much extended, and some variety introduced into the apparatus. That erected by Bramah, in the Westminster Hospital, is shown in Fig. CCXXVI. and Fig. CCXXVII. heats by the circulation of the water, and by warm air, in the manner of a stove.

FIG. CCXXVI.

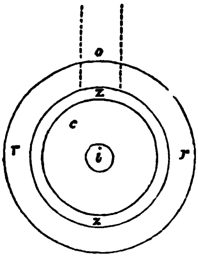
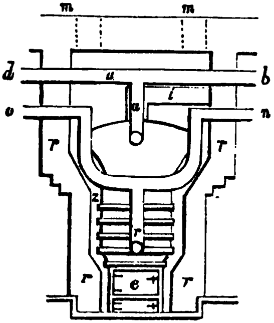
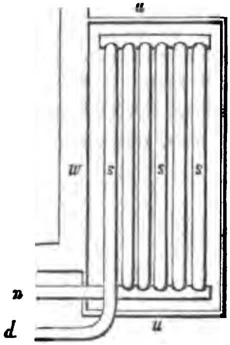


FIG. CCXXVII.



The furnace is contained within the boiler, and its flue passing through it at top, is led by a 9-inch pipe, *i*, into the smoke-flue in the wall. The cylindrical boiler, *c*, is surrounded by a brick wall, *r*, leaving a space of 4 inches round it, which is covered in at top, and forms a small air-chamber. Into this enclosed space the air is admitted from a culvert, *v*, which communicates with the atmosphere under the porch in front of the building, and rising in the circular cavity, is heated by contact with the external faces of the boiler, and finally flows through the valved openings or regusters, *m*, into the hall.

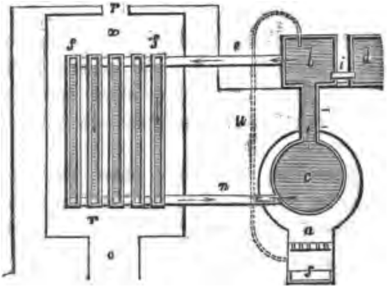
FIG. CCXXVIII.



The hot water for warming the passages and staircases is conveyed from the boiler by the pipe, *a*, fixed under the ceiling of the basement-floor, with branches, *b*, *d*, carried to each end of the building, which terminate in a series of heating pipes, *s s*, arranged as shown in Fig. CCXXVIII. These pipes are inclined from their point of junction, with the branch pipes to the exit by the descending pipe, and the whole are enclosed in a case, *u*, that has the bottom perforated with holes, to allow the cold air to rise and come in contact with the hot pipes, and then to percolate, when heated, through the holes made in the top of the case into the passages in the floor above, *o n*, the descending pipe from each heating-case connected with the return pipe, and inserted in the bottom of the boiler. Small cocks, *u*, placed at the highest points, to emit the air that is extricated from the water. The mean temperature of the enclosed pipes Mr. Bramah stated to be 185° when the temperature of the water in the boiler was 270°.*

Mr. Manby's apparatus is a good example of flat parallel, heating surfaces, arranged as a hot air-stove. It is shown in Fig. CCXXIX. *c*, a cylindric boiler, placed over a furnace, *a*, a pipe rises from the upper part, and terminates in a square enclosed vessel, from which a pipe, *e*, branches to the upper end of a series of flat hollow vessels, *f f*, that communicate with each other; another pipe, *n*, on their lower end, forms a communication with the bottom of the boiler. The flat hollow vessels are enclosed in a chamber, *x*, into which the cold air is admitted through an opening in its floor, and the heated air is conveyed through an opening, *r*, in its roof, into channels which distribute it at the points where it is wanted. The water is supplied to the boiler from a reservoir, *d*, and the water which may be expelled by the expansion from heat, is conveyed by the small pipe, *u*, into a vessel, *s*, which forms the bottom of the ash-pit, to assist by its evaporation, as Mr. Manby thought it would, the combustion of the fuel placed on the grate over it.

FIG. CCXXIX.



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* Appendix to Tredgold, p. 7.

The operation of this apparatus is very simple. The water heated in *c*, flows through *e*, into the air-heaters, *f*, where it is cooled by the current of cold air rising through the opening, *u*, and falls to the lower part of the heaters into a pipe, *n*, which conducts it to the lower part of the boiler, and by this means a continued stream of hot water flows from the boiler into the heating vessels, and preserves their surfaces at a certain temperature.

There is no practical objection to this neat and compact apparatus, except the greater difficulty of keeping the joints in order, when compared to a similar arrangement, where pipes are substituted for the flat vessels.

The preceding methods show the ventilating and warming processes to be kept separate, which are combined in the apparatus indicated in the diagrams, Fig. CCXXX. and Fig. CCXXXI. *c*, a boiler, from which proceeds the circulating pipe, *s s*, placed beneath the floor of the room in a nearly horizontal direction, but with a general inclination from the highest point towards the boiler, *c*. The fresh air is admitted at *n*, and descends in the vertical channel, *a*, into the space beneath the floor, and coming in contact with the heated pipes, is emitted through holes in

FIG. CCXXX.

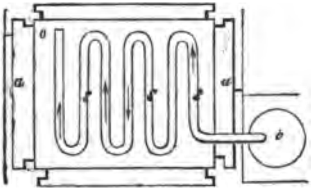
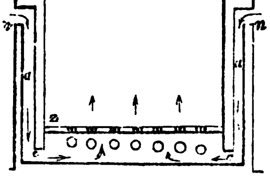


FIG. CCXXXI.



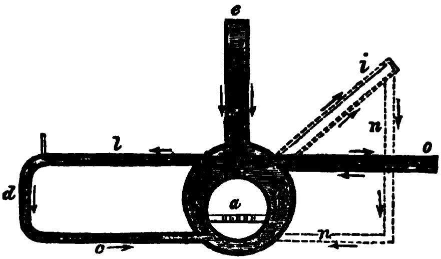
the floor, into the room, and the effete air escapes by the opening, *i*, in the ceiling. This is a very favourable disposition of the heating surface, and one that is often adopted in drying-houses; one of which is shown in the figure.

It is apparent that a similar series of pipes may be placed in a basement chamber, from which channels may branch to the rooms which are to be heated in the floors above.

In all the apparatus, which have been described, the circulation of the water is promoted by what is technically called a return or descending pipe. But in many cases, in which the difference of level is small, the effect does not appear to have been improved by this arrangement.

In the diagram, Fig. CCXXXII., *a*, is a furnace in the inside of the boiler, *s*, with various pipes proceeding from it. If we suppose the pipe, *e*, only to be attached

FIG CCXXXII.

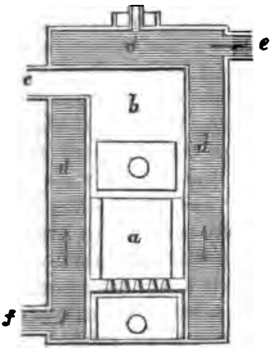


to it and filled with water, as that in the boiler was heated, a circulation would commence and continue by the hottest water rising to the upper part of the pipe, and the water cooled by contact with its surface falling into the boiler. It is clear the same effect will be produced if the pipe, *i*, were substituted for the pipe, *e*; and it is also clear that the circulation would be less impeded than if the hottest water rose to *i*, and descended when cooled through the pipe, *n n*, to the bottom of the boiler, *s*, supposing in both cases an equal quantity of heat to be dissipated. If the heating pipe, *o*, was nearly horizontal, the same effect would take place from the molecular action, the water in the pipe would be somewhat warmer than if it flowed along *b*, descended by *d*, and returned by *c*, into the boiler, as less of the velocity due to the temperature would be lost from friction in the straight pipe than in the return-pipe. In most cases the return-pipe might be altogether omitted, with manifest advantage to the simplification and consequent certainty of the circulating process, the lightest water will always find the highest level, and the less it is impeded the circulation will be the more perfect, and the heating effect will be greater. The arrangement, for instance, shown in Fig. CCXXIV. would have been as effective had there been no return-pipe; each floor or room might have been heated by a separate pipe proceeding from the boiler, and the expense been considerably less by the simpler method.

There are two ingenious devices for continuing a circulation in cases where there is a small difference of level,—the rotary float of Mr. Eckstein, and the syphon apparatus of Mr. Kewley. In some instances they are effective; but perhaps the cases where their use is necessary are not those in which hot water heating is the most proper: they require more attention than can at all times be had from domestic servants, and are easily deranged.

There is usually an endeavour to connect as large an area as possible with the boiler, in order to save the time of the attendants, and ensure a uniformity of effect. This is, however, often very injudicious, particularly in dwelling-houses, where it is most desirable to heat each floor, or certain chambers separately. The water-stove has been occasionally used to supply this defect; but neither its construction nor its effect have been attended to. A section of one of the usual form is shown in Fig. CCXXXIII:—*a*, the fuel-chamber; *b*, the smoke-chamber; *c*, the smoke flue: *d*, a space filled with water, which is admitted at *f*, and rises into *e*: if the pipes are connected, a circulation would then be continued. In bed-room floors, two or more adjoining rooms could generally be conveniently heated by a small stove of this sort placed in one of them. In work-rooms, also, in which the employment is followed at a distance from the fire, and where warmth to the fingers and feet of the worker is desirable, a water stove might be introduced with good effect: the hot water could be conducted under tables or round the room, or to points where it was wanted; and the stove be under the management of those whose feelings were to be consulted.

FIG. CCXXXIII.



The required area of the heating surface is sometimes given by fixing a common boiler on the top of a small Dutch stove, which is constructed with a traversing heating-pipe, like those described in the previous apparatus; and the whole is a ready and convenient contrivance for a working or a sick room.

The velocity with which the water circulates has been attempted to be given by calculating from the difference of temperature indicated at opposite points of the apparatus; but many circumstances in practice affect the motion,—the varying temperature of the air, and consequently of the pipe surface,—the flexures and inclinations and length of the pipes,—the varying rate of combustion in the furnace, and heat of the water in the boiler,—the thickness, material, and surface of the pipe,—its irregular or uniform calibre,—the greater or less skill with which the air-valves are placed, and many mechanical niceties of detail and finish. Most of the data must be assumed; so that to practical men the few rules that have been given are not only useless but often delusive, and hence the uncertainty and varying practice of those who have erected this sort of apparatus.

Some general maxims are however recognized in these arrangements. As the effect of the circulating pipe depends on the temperature of its surface, that will be higher or lower as the velocity of the internal fluid is rapid or slow; all bends or flexures in the pipes should be avoided, and where unavoidable they should have as flat a curve as possible. Angular elbows or knees are most faulty. The ascending and descending pipes should throughout have the same or nearly the same internal diameter, without contractions or enlargements; and where cocks are introduced, their water-way should be as near that of the pipe as possible. It is obvious, that in a series of tubes in which the circulation depends on a minute difference of level, that this should be carefully preserved by proper fixing, more particularly where the direction is nearly horizontal,—a slight accidental depression in a series of pipes will mar the action of an otherwise effective apparatus; and more failures have arisen from this, than by all other causes united.

It is of much importance towards the effect of a hot-water apparatus, that the pipes for the escape of the air extricated from the water should be placed at the proper points. The only rule followed in practice, is to fix them at the highest part of the range, where there is a change of level, as there the air, generally, though not always, is found to accumulate.

The improvements or novelties that have been introduced, are mostly connected with the form of the boiler. They all may diminish the quantity of water which the boiler contains, and increase the area of its surface exposed to the fire; but although each may produce some advantage, it is not unfrequently counterbalanced by aggravating some defect. The quantity of water a boiler contains cannot materially prolong the time of heating an ordinary sized building, and the economy of the more rapid process is at best but doubtful, as the heat accumulated by any mass of water, may finally be given out to the building. In the long run, the Cornish or Chabannes cylindric boiler, with an internal furnace, may be proportioned to expose as large a surface to the fire, with the required capacity as will meet the exigence of most cases that occur in practice, and have that desirable simplicity and strength of construction in which some of the modern forms are deficient. The size of the boiler is proportioned to the quantity of fire surface that may be thought necessary, and not as in a steam-boiler, with regard to the quantity of steam in the pipes; the greater the surface which is exposed to the fire, and the less its capacity, with reference to the cubic contents of the pipes, the sooner will they be heated.

The fire surface of boiler, area of grate, and air-space may have the proportions given for a steam boiler at page 247. Mr. Hood assigns 4 square feet as the proportion of fire surface for evaporating 1 cubic foot of water an hour, estimating every 2 feet square of flue surface as equal in effect to 1 foot of that portion of the surface exposed to the direct action of the fire, with 28 square inches of grate-bar to each foot of surface. When the room is about 60°, and pipe at 200°, 1 square foot of fire surface will be required—

For each 57 feet in length of 4-inch pipe
„ 76 feet „ of 3-inch pipe
„ 114 feet „ of 2-inch pipe

If the difference between the heat of the air and the pipe is reduced, the length of pipe may be somewhat increased.

It is found most convenient to give the necessary quantity of surface by increasing the length, rather than the diameter of the pipe. In practice, pipes of 3 or 4 inches in diameter are most commonly used; and two lengths of pipe of small diameter are preferred to one large pipe. They are more manageable when they want repairs, their joints are made with more facility, and less liable to be out of order; and one pipe only instead of both, may be heated occasionally.

The pipes are connected in the same way as those for steam or water. Spigot and faucet-joints closed with iron cement, as already described, are perhaps as neat and lasting as those made by any other method.

As the heat in a hot water apparatus is about the same as that of steam-pipes, the quantity of pipe required to warm a given area may be found by the table or rules given in the preceding essay. The following rule to find the length of hot water pipe to maintain a certain temperature is given by Mr. Hood, as deduced from more accurate experiments than Mr. Tredgold's, and as more to be depended on in practice.

Multiply 125 by the difference between the temperature to be produced in the room and the temperature of the external air; divide this product by the difference between the temperature of the pipes and proposed temperature of room; then multiply the quotient by the number of cubic feet of air to be warmed per minute; this product divided by 222 will give the number of feet in length of pipe 4 inches diameter required.

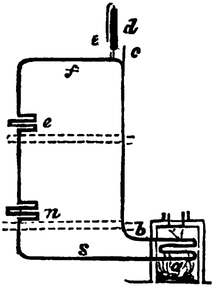
If 200 cubic feet of air is to be warmed in a minute, and the external air at 32°, and the room at 60°, and pipe at 200°, then $125 \times 28 \div 140 \times 200 \div 222 = 225$ feet of 4-inch pipe required. This multiplied by 1·38 will give the length of 3-inch pipe; by 2 of 2-inch, or four times the length of 1-inch pipe.

The weight of coal used is found from the cubic feet of air heated. (See page 262). The time required for heating a building by hot water or steam apparatus is found by dividing the cubic contents of the room, by the quantity of air heated in a minute, the quotient will be the number of minutes required. A room containing 5,000 cubic feet, into which 200 cubic feet of warmed air is admitted per minute, will be warmed in about half an hour.

Where the heating surfaces are introduced into the rooms in the manner shown in Fig. CCIX., the apparatus can seldom be arranged to heat one apartment independently of another, nor can they with their connecting pipes always be made ornamental; and when the pipes are carried to some height above the boiler, there is so great a strain thrown on the lower joints that it is difficult to keep them water-tight, and the apparatus requires frequent repairs. On this account, among others, this variety of the apparatus seldom continues to give satisfaction; especially in private houses, where the services of an engineer are not constantly required for other purposes. In most cases of this kind, it will be found best to confine the entire apparatus to the ground story, and so arrange it as to heat the air, in the manner shown in Figs. CCXXVIII., CCXXIX., CCXXX., and conduct it in the usual way by pipes or channels into the apartments above. The first expense is less, the repairs are easier made, and with much less inconvenience to the family or establishment. The effect is as great by this method as by the other; any part of a building may be heated without reference to another part, and, above all, any one part may be heated slower or quicker,—as all the heat of the apparatus may be thrown upon one point, if necessary.

THE HIGH-PRESSURE METHOD, contrived by Mr. Perkins, is shown in the diagram, Fig. CCXXXIV. A coil of wrought-iron pipe of small diameter placed in a furnace, *a*, is continued and conducted through the building, and the necessary quantity of surface is given by forming coils, *n*, of the pipe which are placed in the rooms to be heated, and the pipe is finally returned, as at *s*, into the furnace where it is joined to the coiled pipe, *a*, and thus forms an endless pipe. At the highest point of the heating pipe, *f*, is another pipe, *d*, of a larger diameter,

FIG. CCXXXIV.



placed either in a vertical or horizontal position, and which has a capacity from $\frac{1}{10}$ to $\frac{1}{12}$ of all the water in the endless pipe. This is called the expansion-pipe, and into which the water rises as it expands in heating to prevent the apparatus bursting. The filling-pipe, *o*, rises to the level; and no higher; of the lower part of the expansion or safety-pipe.

The tubes being thus arranged the whole series, except the expansion-pipe, is filled with water by means of a force-pump applied to the filling-pipe, *o*; and as it is of importance to free the endless pipe thoroughly from air, the water is pumped several times through the tube until this is accomplished. The endless-pipe being thus filled with water, and the expansion-pipe empty, every part of the apparatus is then strongly and hermetically closed. The endless-pipe, having a bore of about ½ an inch, and being ¼ of an inch thick, the apparatus is capable of sustaining a very great pressure.

Its action is the same as that of the chicken-stove of M. Bonnemain. The water heated in the furnace-coil rises into the upright pipe, and then flows on a declination towards the coils placed in the apartments, and gradually giving out its warmth to the air of the spaces it flows through, returns greatly reduced in temperature through the pipe, *s*, into the lower part of the furnace-coil, to be heated and rise upward again continually; the difference in temperature between the ascending and descending columns producing a continuous circulation throughout the apparatus.

From the manner in which the pipes are closed from the air and placed in the furnace, the water they contain may be raised to a very high temperature. Mr. Perkins states the average at about 350°, but in practice it has been observed this is considerably exceeded.

FIG. CCXXXV.

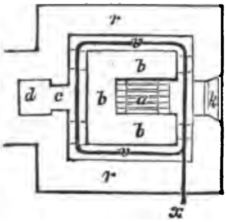


FIG. CCXXXVI.

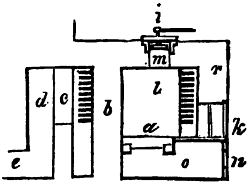
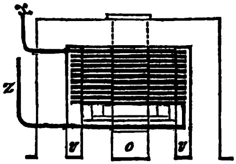


FIG. CCXXXVII.



The three following diagrams will give some idea of the way in which the furnace was constructed to heat a portion of the British Museum. Fig. CCXXXV. is a plan of the furnace taken above the grate; Fig. CCXXXVI. a longitudinal section taken through the centre of the furnace; and Fig. CCXXXVII. a section, supposing the front wall of the furnace to be removed; *r r*, a wall of common bricks, 9 inches thick, which encloses the furnace on its four sides; *b b*, a wall 9 inches thick, formed of Welch fire-lumps, that enclose the fire-chamber on three sides. From the face and ends of this wall fire-bricks project, to support the coiled pipe, *o*, placed in the flue. The intention of this wall is to prevent the too rapid abstraction, by the coil, of the heat from the fire which thus comes in contact with it at the opening in front only, where the hot gases turn into the back and side flues in which three-fourths of the furnace or boiler-coil is placed. The roof of the furnace is formed of Welch lumps, in which is an opening, *m*, fitted with a moveable cover, for supplying the furnace with fuel (coke or anthracite coal being preferred). The ash-pit, *o*, is enclosed with a door, *n*, in which there is a register; *k*, double fire-door to an opening in the wall, for clearing the fire-place and furnace-bars from dust and scoria. This has a dead plate, to separate the ash-pit from the heating flues; *x*, heating-pipe, rising from the boiler-coil which passes round the internal wall, in the flue, *v*, and is thus defended from the radiant heat of the fuel on all sides but one. This heating-pipe is continued from the upper part of the fire-chamber into the building; *z*, the return-pipe which enters the lower part of the furnace, and passes through the bearing bars of the fire grating, to prevent their overheating. The dust and soot fall to the bottom of the heating flue and prevent the coil being clogged.

The furnace is placed in a vault in the basement story, and the pipes, *x*, *z*, are carried up to a height of 40 feet in a flue to two coils of pipe; one containing about 300 feet of pipe, and the other 400; about 140 feet being used for the ascending and descending-pipe in the flue, and 150 in the furnace for the coil boiler. The room containing 360 feet of pipe, is 43 feet long and 30 wide, and lighted by large skylights in the ceiling, is raised in winter to 65°, which is a high temperature to be maintained in a room on this construction, even with this liberal allowance of heating surface.

Mr. Perkins made several skilful arrangements of his pipes in adapting his apparatus to different situations. In one example he substituted a series of pipes for a cockle, with excellent effect.* The pipes were arranged in an enclosed chamber, from the roof of which channels branched to the several points that required heating, and cold air was admitted into this chamber through perforations in its floor (similar to that shown in Fig. CCXXIX.), which was thus brought in contact with the hot pipes, and rose in a warm stream into the building; a disposition perhaps the most favourable that could be practised with such highly heated surfaces, as the hot air could be properly attempered by the cold air drawn from an underground culvert about 300 yards long, before its admission into the building.

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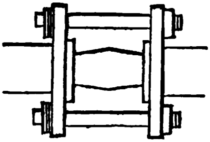
* Richardson, on Warming, &c., p. 44—48.

The adaptation of these methods of heating to dwelling-houses is a point that often is, but never should be lost sight of by inventors; for however flattering it may be to their ingenuity to succeed in the construction of large apparatus for extensive buildings, the benefit they confer on the public is trifling when compared to what it would be were their contrivance made useful for common sized rooms in small houses. The way in which Mr. Perkins heated an office shows, however, that although his high-pressure apparatus has mostly been erected on a large scale, it may be used with advantage to heat an ordinary sized parlour. In the case alluded to, he placed a few bends of the wrought-iron pipe at the back of the grate for an open fire, from which two pipes were carried round the skirting, and the filling and small expansion tubes were placed in the hearth recess. The open fire was made in the grate as usual, and heated the water in the bends, which flowing in the pipes diffused an equable and genial warmth round the room,—a hint that might be extended, to produce a great deal of comfort in places that are now without any; and the boiler-coil could be attached to a low-pressure as well a high-pressure circulation.

The way in which the pipes are joined is the same as that followed in connecting gas-pipes. It is described in page 283. Fig. CCXXXVIII. shows

FIG. CCXXXVIII.



what is called the cone-joint, and is strong and quickly made. The cone is inserted into the ends of the pipes to be joined, and is made tight by two screw-bolts, (as shown in the figure), which will be understood by inspection.

For some other details of this method Mr. Richardson's treatise may be consulted with profit, lowering however somewhat his estimate of the advantages of a high-pressure circulation.

An obvious superiority of the high-pressure apparatus lies in the ease with which the heating-pipes, from their flexible material and small size, may be introduced into rooms into which larger and unsightly pipes would be inadmissible; in the ease with which they may be kept in working order, and the facility with which they may be arranged to meet the exigencies of particular situations. The boiler coil and heating-pipes contain much less water than the boiler and pipes of a low-pressure apparatus, hence it is sooner heated; and as the pipes may be more spread in the space, their heat should be more equably diffused.

On the other hand it is open to some serious objections; the pipes being hermetically closed, a very high temperature may be given to the water, and an enormous and dangerous pressure by this means thrown on the apparatus. Mr. Perkins stated that the temperature in the pipes seldom exceeded 350°, which is equal to a pressure of about 135 lbs. per square inch, and greatly exceeds the maximum strain, or 50 lbs. an inch thrown on a high-pressure steam-engine. But in practice the temperature of the Perkins apparatus has been found to vary from 220° to 550°, the latter temperature equivalent to a pressure on the pipes of 1,100 lbs. per square inch,—upwards of 71 atmospheres. It may be admitted, that the hazard of bursting is merely relative; for as Mr. Perkins proves his pipes when cold to resist a pressure of 2,800 lbs. per inch, there may be, and perhaps is, less danger in working his apparatus at a pressure of 1,100 lbs. on the inch than a Trevithic engine working under 50 lbs. on the inch. We know, however, from experience, that from use the material of the pipes loses its original tenacity, and that pipes which have when cold resisted the pressure stated by Mr. Perkins, when heated, have given way even below the temperature at which they had long been worked with safety. The fear of danger, if its actual presence in the average of cases be disputed, is no doubt greatly increased by the knowledge that no method has been devised to regulate the pressure in the sealed pipes like the safety-valve of a steam-engine, nor any means to prevent a careless attendant on the furnace at any time endangering the safety of the apparatus.

In many cases the high temperature of the pipes is objectionable from surfaces at 300° or 400° rendering the air insalubrious by decomposing the animal and vegetable matters suspended in it. On this account a high-pressure pipe is not superior to a German stove, whose surface is generally above 300°; and a pipe at this temperature cannot be placed without danger near wooden skirtings or floors, or combustible materials.

Although the pipes can be spread into all parts of a building, the heat is not very equally diffused, as the pipe surface sometimes varies 200° or 300° at different points of the apparatus. This fact marks in a clear manner the defective circulation in the pipes, mainly, from the friction occasioned by the number of their bendings and angles; were these diminished the pipes would have a more uniform temperature, a larger quantity of air would be heated by the same surface, with the same quantity of fuel expended in the furnace, with a less pressure on the pipes.

The number of these convolutions, the ever-varying temperature of the furnace, and the small diameter of the pipes, renders futile the attempt to ascertain the velocity of the circulating water. That there should be any motion whatever in the water at certain points of some apparatus that have been erected, is a circumstance that seems to set at nought most of the common notions of hydraulic action.

The quickness with which the apparatus may be heated depends in some degree on the proportion given to the boiler-coil. From a seventh to a fourth part of the whole length of coiled pipe has been placed in the furnace; the greater the length so placed the more rapidly the sealed pipes are heated.

From the smaller quantity of water in the furnace-coil and sealed pipe, the Perkins apparatus is sooner heated than a boiler and larger pipes on the common construction. But there is little difference in the time in which the air of a building is heated by the high or low-pressure apparatus, where the former is worked at a pressure about 350°, for the mean temperature will not then exceed 220°.

This greater rapidity of heating is however no advantage in many situations. The apparatus being as quickly cooled as it is heated, and its general temperature rapidly fluctuating at every variation of the combustion in the furnace, in all places where permanence and uniformity of temperature are essential, the low-pressure apparatus in which a great body of water acts as a regulator as well as a reservoir of heat is to be preferred; and it is obvious that the same quantity of heating surface at the same temperature in every variety of warming apparatus heats the same quantity of air. From the comparatively small surface of pipe exposed to the radiant heat of the furnace, and the high temperature at which the smoke escapes from it, the coiled-pipe boiler has been thought much less economical of fuel than the low-pressure boiler. It is not found to be so in practice. All circumstances being similar, the high-pressure coil requires about the same quantity of fuel that is necessary for a common boiler. The construction of the furnace is one of the most ingenious and well-designed parts of the Perkins apparatus—that of which some diagrams have been given; and another erected for Mr. Babbage, are entitled to great praise. It is confessed that accidents are not more frequent with this than with other apparatus: but when the patent is thrown open, the competition of tradesmen, their careless selection of materials, imperfect workmanship and ignorance of effects, must be calculated on as prodigiously enhancing the chances of future accident, which are now trifling in consequence of the great care bestowed by Mr. Perkins in the construction of this hazardous apparatus.

The draco has been noticed in the Third Essay; to which may be added that Cameron, in his account of the baths of the Romans, also gives a figure of an ancient coil-boiler, most probably formed by a Roman workman.

ESSAY XVI.

THE effects of temperature, which are of consequence in all diseases, in some are of vital importance; but yet, says Beddoes, hitherto no apothecary has invented the art of dispensing heat and cold, and the means of applying them generally or partially have been very imperfectly provided for the use of the sick. In most cases the physician is prevented from recommending a patient to be placed in air of a certain quality, from a supposed difficulty in producing it; or the friends of the invalid are indolent, and disposed, when anything beyond mere household means,—such as a warming-pan, or hot blankets, or hot water,—are required, to consider every thing not comprehended in the ordinary routine of practice with dislike; and the medical attendant knows that as they must administer or superintend what he prescribes, if they do not accord a willing and intelligent co-operation, his exertions in favour of the invalid are irksome or neutralized. In other cases the relatives are poor, and unable to meet the expense; or they are parsimonious; or they are ignorant and doubtful of its efficacy.

Every room which we inhabit is a shelter for medical purposes which we seek almost intuitively, from feeling many natural functions can only be performed in a certain temperature: though those only which are heated and ventilated with the intention, to promote the comfort and aid the recovery of the sick, are for distinction called medical climates. There is no mechanical difficulty in heating a room to produce any variety of climate; nor will increased trouble or inconvenience follow from its adoption; on the contrary, it will diminish the occasions for attendance in a variety of ways:—if the invalid be poor, his improved climate will cost less than the one he previously lived in; and the parsimonious will receive a boon instead of being required to make a sacrifice.

According to physicians, steady warmth, in consumption, for instance, creates an exemption in favour of those who would become a prey to that disease in a cold variable climate; and on this account a residence in a warmer region is often recommended to invalids. Where a change of country is not expedient, a warm artificial climate is considered the next best alternative.

Le Grand, in his "History of Auvergne," relates that in Cantal and Salens the wood is so scarce, that in winter the peasants are forced to lie abed most part of the day to keep themselves warm. On the Mount D'Or, their habitations are divided into the house, the stable, and the barn. As soon as the cold weather sets in all the family retire to the stable, and are generally joined by other families; for if one person has a better stable than the rest, it is fixed upon for the rendezvous of several families. The horses, cows, oxen, and sheep occupy two ends of the room; the beds of the family,—a sort of boxes placed at the feet of one another against the wall, and filled with straw,—are placed in the middle, as being the warmest part; and the inmates pass through the range of cattle whenever they go out of the stable into the house, which they do thrice a day to eat their broth. But these people, Le Grand remarks, are subject to fevers and other maladies, owing to the air they breathe in their cow-house, which is corrupted not only by the exhalations from the dunghills, which are never removed during the winter, but also by the respiration of the animals.

Nevertheless it was observed that although unwholesome and nauseous in general, in some cases it seemed to have a beneficial effect in abating the symptoms of a consumptive disease.

"After an illness, (says Madame Mezeray), during which I took little care of myself, I fell into a consumption. At length I spit blood in clots, and had other bad symptoms. I lost my sleep; and being as ill as possible, I had several consultations with the first physicians in Paris. They concluded my complaint was too far advanced to leave any hope of a cure: but they prescribed ass's milk, and exercise on horseback; which last I was too weak to take.

"I was nineteen. I beheld my end approach with deep dismay. One day, when I was bewailing myself, a very sensible friend of mine paid me a visit. In the midst of his condolence he said, since all the physicians abandon you, let me bring you a man who is treated here as a charlatan because he is not known, but who in my opinion is a man of merit. He brought him. I spit blood in clots. I was in such violent pain, and my fever was so high, that I cried out,—'Ah, if there be yet time, save me!' He promised to do all in his power; but I heard him say, in a low voice, that it was very late. He made me promise to follow his orders exactly, how painful soever they might be; and I kept my word. Finding that a remedy he prescribed had not the desired effect, he gave orders for a cow-house to be prepared for me, which was finished in a day, in a coach-house belonging to my house. They broke open a window, and contrived stalls for three cows; a wooden railing, high enough for me to lean upon, was all that separated me from the animals. My bed was placed upon planks about a foot from the ground, the better to let the filth run under, and the planks were purposely ill-joined that the vapour might rise through them; and this was so strong that every thing white which was brought in became reddish in a short time.

" My apartment was divided into two rooms. That which I lived in was pretty large, and held a bed with curtains,—surrounded by a gauze blind to keep away the flies, which always abound in stables, and are particularly insupportable during illness; a wooden table, two straw chairs without cushions, and bare walls—such was my chamber. There was a sort of anti-chamber for the woman who took care of the cows. My surgeon and waiting-maid lodged over head. I had bells to call them at pleasure.

" I soon spit less blood. After being a week in the cow-house my legs ceased swelling. Other symptoms improved. The night sweats I almost always had continued long after, but finally left me. From the moment I entered it I renounced every species of food, except milk: I did not taste bread even for nine months. People came to see me as an object of curiosity. The Duchess of Orleans paid me a visit; and, after my recovery, she recommended Doctor Saiffert to the Duke, which was the means of making his fortune. Here I remained nine months without intermission, with the exception of a few rides in a close carriage. In short, he saved me at the expense of my hair only, which all fell off. It was necessary to repair my fore-teeth, which I had neglected in my illness; and I was absolutely forbid to play on the harp, which had made my breath very short; but what is all this in comparison with life? I am now become quite a strong woman; and although not so vigorous now at thirty-six as when I was nineteen, for all that I think I shall weather life out very well." *

"In daring to commit such cases to the public," says the benevolent and enthusiastic Beddoes, "I feel that I am preparing a feast for those who resort to ridicule, if not as a test of truth, yet as the supreme delight of rational and immortal minds; but I hope also to interest those whom no ludicrous accessories can prevent from viewing with complacency the first awkward and unsteady advances towards an useful object."

A daughter of the celebrated Priestly having applied for advice; "In her case to have placed the smallest reliance on medicine," says the doctor, "would have been to encourage a fatal delusion; and there only remained the choice between a sea-voyage and a constant residence with cows. She asked me which alternative I should prefer in her situation. I told her undoubtedly with cows." And she made the experiment under his direction.

The stable provided for this lady, was 24 feet long, 14 feet wide, and 9 feet high. A space, partitioned off, was sufficient to contain a bed, a table, and allow a little room to move about in. Its floor, formed of rough boards, was raised a few inches above the ground of the stable. The windows were ill-placed; they faced the north, on account of the convenience of communicating with the house. They should have faced the south.

Two cows were placed in it for a month, and three cows for the remaining five months. There was a

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* Medical management of the Consumptive, p. 38.

small stove in the part where Mrs. Finch lay, which was used for two months, for nearly half the day, but afterwards only in extreme frost, or on the room feeling damp.

The temperature for two months was kept from 60o to 65 °, afterwards from 65° to 70°, but in general at 68°. The temperature was found best between the two latter temperatures, and the air at a medium between excessive damp and too dry heat of a stove. The stove lighted in the morning to dry a little of the moisture collected during the night was pleasantest to her feelings. Successive generations of flies were found to be a great nuisance, and the cordage and other parts of the bed were speedily rotted. The vapours however gave no body cold, nor did any attendant suffer from a longer or shorter continuance in a medium so much warmer than the external atmosphere. On the contrary, one lady who paid many and long visits had her symptoms of chronic rheumatism much alleviated.

The management of the cows was found to be a matter of some importance. For a month or six weeks they were allowed very little straw, nor was their standing cleaned; afterwards they had plenty of straw, and their beds were kept tolerably dry. Hay of the best quality, and free from dust, was found preferable on all accounts, and straw that was clean and dry. The cows were watered twice a day, but not so sparingly as they might have been. The better the hay they were supplied with the less water was necessary. Their horns were noisy, particularly during the night; on that account, young cows without horns would have been more desirable, and such as were young in calf; and halters better than chains to tie them with.

Mr. Finch observed, that if the patient could have been on a low floor above the cows many disagreeable circumstances would have been avoided.

The effect of their wet was all along nauseous to a stranger, but the feelings of the patient should alone be consulted. The genial warmth relieved oppression on the chest, took off restlessness, and produced a feeling the lady described by comparing it to nourishment conveyed through the pores of the skin; and so different were her feelings in the cow-house to what they were before, that she would have been reluctant to have changed her apartment for the night, however she might have wished a cleaner and more cheerful one for the day. After the first night, the air was, to use her own expression, *balsamic.*[*]

In this she remained through autumn and winter, for six months, with three exceptions. About a week after her entrance she slept a night out of the cow-house, when the hectic symptoms and night sweats which had left her returned. Six weeks afterwards she lived for three days in an apartment 3° warmer than the cow-house. The night sweats did not return until the third night, and her breathing became laborious; instantaneous relief took place on returning to the cow-house. On a subsequent removal for a week no relapse occurred.

The effect on the cows living in a climate at this temperature was not observed by the doctor, but it is pleasing to reflect that while alleviating human suffering, the second mothers of mankind were benefitted themselves. "A cow," says Anderson, "to enjoy existence requires a temperature not lower than 50°, nor higher than 70°." But he sets one limit too low: a cow does not appear to feel pleasure in a climate under 60°; and we have seen them in a north-easterly wind prefer a moist warm cow-house at 75° to one 10° lower.

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[*] Medical Management, &c., p. 47.

During the following winter Mrs. Finch confined herself to an apartment heated artificially by a stove; but she then said, "I still prefer the *air* of the cow-house to my warm room, although it is of a good size, and lies to the sun."

Another method of using the same kind of heat was tried by Dr. Beddoes, to ascertain whether the effect was owing to any cause but a high uniform temperature, and the gases given out by the skins and breath of the animals, and fermenting vegetable substances. A stable with two stalls was selected for the experiment. One stall was filled very full of the materials used by gardeners for hot-beds. When the hot-bed was in strong fermentation the temperature rose to 64°, and the patient felt relieved. Occasional supplies of stable and cow-house soil were added as the first hot-bed sunk. As the winter advanced, and the warmth from the fermenting mass decreased, the stable became too cold, and it was necessary to introduce a stove; at 60° and below that temperature the patient's symptoms became more severe. 70° was an agreeable warmth, though he could well bear a higher.*

Vessels containing the fermentable substance might also, as the doctor suggested, be introduced to warm a room, and be easily regulated by covers, and the vessels removed entirely the moment that the exhalation was found to disagree or be offensive.

For another invalid double doors and double windows were added to a bed-room. The fire-place was bricked up round the flue of a cast-iron stove for giving out heated air; one of the sides of the stove was pierced, to receive the end of an iron tube, *a*, the

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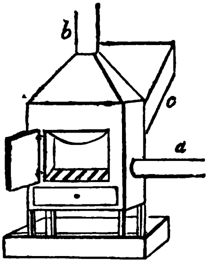
* Medical Management, p. 71.

FIG. CCXXXIX.



other end of which passed through the wall of the apartment, by which means the fuel was consumed by the external air. This tube had a damper to regulate the supply of air to the fire when it burned too briskly. The temperature of 70° being most agreeable, this heat was kept up steadily.

Two other invalids, whose rooms were heated in a similar way, found the most agreeable temperature to be 65°. At 54°, others were disagreeably affected by the cold.

On another occasion a hot-air stove was placed in the bed-room, and in a sitting-room which communicated with it; a fire was occasionally made in the open grate. The stove fire was supplied by air conveyed through a pipe from without; and it was easy to keep up night and day a pleasant temperature, varying between 60° and 65°.

It was remarked by all these invalids that the *stillness* of the air in their rooms became much more agreeable than the currents and unequal distribution of heat from a common fire. No complaints were made of any disagreeable smells being produced by the iron stoves.

About 1802 Dr. Adams broached the project of constructing a building adapted for the reception of pulmonic invalids, which should be kept throughout the winter at a certain warmth so as to imitate the genial southerly climates. Dr. Pearson also, in 1808, endeavoured to draw attention to a similar scheme.*

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* Phil. Mag. Vol. xxxi.

In 1809, a regulated climate for asthmatic patients was recommended by Dr. Buxton; and on one occasion he succeeded in producing what he considered a salubrious atmosphere, by means of a common ironing stove 12 inches long, 9 inches wide, and 9 inches high, placed 5 feet from the wall of a room that had 1,337 cubic feet of space; but from the construction and small size of the stove, and high temperature of the room, the surface must have been often at a red heat, and the air of very indifferent quality.

In 1814 Dr. Kentish greatly improved on Dr. Adams' notion, in his account of a "Madeira House," which should contain library, baths, garden, ambulatories, riding-house, and other accommodations for the consumptive, kept at a summer temperature throughout the winter.* Mr. Vallance, in 1821, spoke of a kind of immense hotel, with a public room of such a size as would be sufficient for ample exercise, and in which, though all would partake of the benefit of the general arrangement, each would have a room or a suite of rooms to himself: and a few years afterward Dr. Pearson lamented the failure of his early project, on "account of the many thousands of persons who were living in the kingdom in a state of bad health, not remediable, nor even capable of relief, but by warm fresh air of suitable degrees of temperature, which is *nowhere* obtainable, except perhaps for a short time, in *any* climate." It has often been tried by individuals on the scale of an ordinary lodging-house, and at distant intervals advertisements have appeared, stating where rooms could be had, fitted up to accommodate persons who required a warm atmosphere; but apparently the establishments have had an ephemeral existence only. The notion of a public Madeira House, does not seem to be a popular one: it has too much the character of an hospital to gain the favour of persons in the better ranks of society; and it could not perhaps be adapted to the convenience and means of those in humbler stations, who form the bulk of sufferers in most cases of pulmonary disease. Nevertheless, its greatest advantage may be reaped by the poorest invalid who will bestow a trifling care in heating and ventilating his bed-room or parlour.

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* Account of Baths. Appendix, p. 48.

† Tredgold. Principles of Warming, p. 300. 1824.

Medical writers on climate, as a remedial agent, seem generally agreed that warmth, and equability of temperature with a certain degree of moisture is essential to its efficacy, especially in pulmonic affections. Dr. Thomas Young observes, that the greatest uniformity of temperature is obtained in a sea voyage to a warm climate, in which the variation seldom amounts to half as much as in the most favourable climate on shore.* There is not a spot frequented by invalids in the most genial regions of Europe where the natural winter and spring climate would not be most injurious to a consumptive person exposed to it; and there are seasons when fires after sunset are welcome even to the healthy in the genial Island of Madeira. In England no one place in spring has much advantage over another in point of salubrity, or where a person without caution would not undergo some loss of health or uneasy sensation; nor where, if he were consumptive, he could venture a dozen times during five months in the year to enjoy exercise in the open air—or for seven months could be without a fire in his chamber.

The degree of benefit produced by the warmth alone of the air cannot be assigned, nor that due to the moisture. Beddoes found that a certain temperature was indispensable, or the patients lost ground, and that heated air only was inadequate to relief. Another medical author, in corroboration of this statement, says, that in the West Indies negroes threatened with pulmonary disease were sent to live for a period in the boiling-house, which is commonly filled with vapour; and the practice was very often successful in restoring health. In a room for habitation by the consumptive, means therefore should be provided for maintaining the air at a certain uniform temperature, at all times, and which should contain a certain quantity of moisture, and be frequently renewed without sensible draughts or currents. The air admitted to supply the ventilation should be free from local impurities.

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* Phil. Mag. Vol. xli. p. 256.

As the apartment is to be inhabited between October and May, it is desirable, for the preservation of warmth, that its windows should have a south aspect, and it will generally be found convenient to select the apartment (of one or more rooms) on the uppermost landing of the staircase, or one entering from a passage, a part of which may be formed into a small antechamber. Two rooms communicating with each other are to be preferred.

Much of the comfort of the invalid and the attendants will depend on the way in which the door is managed that separates the sick apartment from the house.

Double doors fitted very closely will prevent the entrance of chink winds; but unless the space between them be sufficient for a person to stand in, and shut one door while he opens the other, a great portion of the warmed air will escape every time he enters or leaves the room. If the doors cannot be conveniently placed at a proper distance apart, a curtain-porch may be substituted. This is readily formed by a slight bracket, with a projection of not less than 18 inches, placed over the door from which a wide curtain is suspended, and falls to the floor; this is fastened to the architrave of the door, or to the wall, by nails, or held in that position by a lath nailed over its edge, so that when the curtain hangs to the floor the door may be open, and no air escape from the room. By means of a cord attached to the lower edge of the curtain, which goes through a pulley or a loop fixed to the bracket, it is drawn up like a Venetian window-blind by a person entering the room, and let down before the door is opened; this is perhaps a better description of porch than that formed by two doors, and may be made, where that is desired, to have a certain degree of elegance.

When the windows are well fitted and air-tight, the quick opening or shutting of a door invariably draws the smoke from a fire or stove into the room. Double doors or a curtain-porch lessen this evil, which to invalids occasions much inconvenience, particularly where coal is used as fuel.

Double windows also should be used; and they will be found most agreeable if the temporary one be fixed on the outside of the room window; the space between them may be filled with flowers, or be used as a reservoir from which to draw air to replace that emitted by the ventilation. If used for this purpose the outer window should have one of its panes fitted with a valve to be opened or shut from the inside, and in all cases made air-tight except at the valve. If the room opened into an air-tight glazed verandah, it would be unobjectionable.

The method of warming the apartment is the next consideration. Where the whole house is heated by a steam or hot water or hot air apparatus, nothing further will be required than to give the necessary moisture to the air heated by these means: and to provide for the ventilation by the common methods.

An open fire on all accounts is to be discarded for an air-stove or a hot water or a Dutch stove.

A water-stove, like that shown in Fig. CCXXXIII., would be unobjectionable, on account of the certainty of its surface not being overheated: and the greater the quantity of water that surrounded the fire, the more uniform would be its action, and after it was heated it would longer continue to impart warmth to the room, —which is a great ease to the attendant where the fire is kept up, and the apartment warmed to the same degree, as it always ought to be night and day. By surrounding it with a casing, at the distance of an inch-and-a-half, like the stove shown in Fig. CLXXIII., it may be employed with advantage, when the air from without is to be heated as it should be before its admission into the room.

It is obvious that any variety of stove may be used with good effect when its heating surface is properly proportioned to the fuel-chamber. An air-stove, such as that shown in page 195, in most cases is to be preferred. The Arnott stove is also a good apparatus; from its ingenious self-regulating mechanism, it requires little attendance during the night, to keep up an uniform climate. Whatever stove is selected its top should be flat, for the convenience of setting things on it to warm; and elbows in the smoke-pipe, proceeding from the stove to the chimney, should be avoided: the smoke-flue is to have no communication with the room except through the stove: the height between the upper edge of the fireplace door and the lower edge of the smoke pipe should not be less than from 7 to 10 inches, and the pipe placed as near the top as possible. When this is placed low the smoke will come into the room, when the fireplace door is opened.

The room, being made almost air-proof with double doors or curtain-porch and double windows, the air, to supply the ventilation, may be drawn from a pipe or channel-opening at one end to the interval between the stove and its casing, and at the other to the external air or to some room communicating with it, and a branch from this may be introduced into the ash-pit to supply the combustion. The ventilation may take place through an opening made into the space between the double window, or through an opening fitted with a valve made near the ceiling into the smoke-flue. The warmed air admitted will be regulated by the quantity of the effete air that is allowed to escape at the valve, which at all times must be adjusted to the feelings of the invalid.

Or the ash-pit may be made nearly air-tight, by a double door, and a pipe with a valve inserted into it be carried up within a few inches of the ceiling. The effete air will be drawn into the ash-pit, and rise through the fire into the smoke-flue, in a quantity that is regulated by the valve. Or a pipe may be placed in the furnace, in the way practised in the Chabannes stove, (page 91) and connected to the ventilating pipe, which will also draw the effete air into the smoke-flue; this is the better method, as the ventilation is then independent of the supply of air to the fuel.

The double window is of much use in preventing the conduction of heat by the glass windows, and it is equally useful in preventing the glass condensing the vapour in the air in contact with it. In common cases this is a process that proceeds so rapidly that when the room is very warm, and the weather without very cold, it is difficult to keep the air sufficiently moist, and the condensed vapour runs in streams from the window: the air will then seem moist, though in reality it will be uncomfortably dry. This effect is greatest in the day time; after sunset the use of curtains and shutters makes it easier to preserve its hygrometric state somewhat regular. Dr. Beddoes did not observe the quantity of vapour in the cowhouse air, nor in the stove-heated rooms. In two instances within our own knowledge air at 60° was not agreeable when nearly saturated: it felt damp and chilly. At 71°, and at 76° the air, when nearly saturated, was found to be bland and refreshing; and was particularly so at the higher temperature, with a movement barely perceptible. In these cases it was remarked, that a very small degree of ventilation was required by the invalid; and that for hours its total cessation occasioned no uneasiness. A very dry air at 74°, with its dew point at 43°, was not unpleasant; but moist air was breathed from choice.

The warmed air is easily supplied with necessary moisture by a pipe from the water stove, or by a large flat open vessel of water placed on the top of the stove, or exposing a surface of moist exhaling substance such as wetted cloth to the air of the room, or more neatly by the method practised by Dr. Arnott in his stove, (page 230) placed in the Custom House.

Two rooms, which communicate, have many advantages. In one case, each had double windows and doors, and an air-stove with a small boiler for moisture, and was ventilated independently of the other. The rooms kept at a high temperature night and day, were so easily regulated that the temperature never fell in five months below 67°, and that only for two hours: making one room a reservoir of heat for the other was found particularly convenient in the cold weather, when there was occasionally a frequent opening of the doors. The ventilation was by an opening near the ceiling into the chimney: a moveable pane placed in the outer window was never used.

When either of the rooms was not occupied by the invalid, the air was invariably raised several degrees *above* the regulated temperature, and deprived of its moisture, and the ventilation made ample.

Over the fixed sofa cover it was found indispensable to have a moveable thick cotton one, with a second to replace it. The curtains were hung so that their folds should retain no dust; and a double set of them was provided. A carpet covered the whole floor in the sitting-room, and was chosen thin and light for the convenience of being easily removed; and there was a second of the same description.

Every precaution was taken not to raise dust. The ashes from the fire fell into a pan of water, and all sweeping and dusting was avoided. Nothing was done in the morning in the sitting-room, except replenishing the stove with coke. The carpet was taken up every night when the invalid retired to rest, and the other carpet laid down. The curtains were taken down once a week at the same time, and the fresh ones put up. The sofa cover was changed three times a week. The floor of the sitting-room was washed or sponged at first twice a week with hot water, before the clean carpet was laid down; latterly this operation was repeated every night;—nothing gave the sensation of freshness so much as the change of carpet and sofa cover: and on those mornings when carpet, sofa cover, and curtains were all changed at once, and the room at 74°, and the dew point about 67°, it was felt by the invalid as if

> "The air of Paradise did fan the house,
> And angels officed all."

The bed-room was managed in the same way; with the exception of the floor's being sponged twice a week only, and in the morning. The sheets, blankets, and pillows were always removed during the day, and exposed to a current of warm dry air in a drying-closet: no indication of dampness or rotting ever was observed on any thing in the apartment.

Mrs. Finch found her bedding rotted, which was very likely owing to the furniture, being *under* the temperature of the air, and then there was a deposition of moisture. This in all cases may be avoided. With ordinary attention the walls of the room will be rather above than below the temperature of the air; in which case the hangings, bedding, and other furniture will be dry. Woollen curtains are preferable to cotton, and a hair mattress to a feather bed. In a room warmed from 70° to 75°, bed-curtains will be found a great incumbrance: and heavy clothing, one of the many miseries of the invalid, will not be required.

To the poor these accommodations are unattainable; a single room, which must often serve for sitting and bed-room, is the most that can be afforded,—and less expensive methods than double windows, double doors, and air-stoves, must be resorted to, to adapt it to their means and their wants.

In every case, however, a Dutch or German stove is essential: it is easily managed, very effective, cheap, quickly set up, and may be used to perform most culinary and domestic processes.

The common sort of wrought iron plate-stove is usually made with feet, to raise it from 6 to 9 inches above the hearth, but the feet should be taken away, and the stove set on the plate that serves for the bottom of the ash-pit. A stove, 9 inches on the side and 18 or 20 inches high with a fireplace 6 inches square and as many deep, would be sufficient for a room 15 by 12 feet, and 9 feet 6 inches from floor to ceiling with a common-sized window. The front of the fireplace is closed with a fireboard, in which is a hole to admit the smoke-pipe.

Wherever a stove is used in a closed room, great care is necessary to make and keep the fireboard, and the opening for the stove-pipe, air-tight with regard to the room; especially where the stove is small, and the flue wide. Where it can be done, the opening of the pot on the chimney-shaft should be reduced to the size of the smoke-pipe: without this precaution, when the fire in the stove gets low, the carbonic vapour in the flue has its temperature so much reduced by the descending air that it finds its way through the crevices into the room. Much of the stifling feeling experienced from stoves arises from this cause.

To prevent the entrance of the cold air, and escape of the warm, slips of paper are to be pasted over the edges of the window sashes and the window frame: and over all chinks in other parts at which air can enter. This, in town, will also exclude much dust as well as *sound*, which is as distressing to the sick as the other.

As a substitute for the second window, thin sheets of writing-paper are pasted together and stretched on a frame, which is fitted into the window at a few inches distance from the glass, and the paper coated with oil or varnish; this screen effectually excludes the air of the room from contact with the glass, and intercepts very little light. Or a piece of thin muslin is stretched on a frame and rubbed over with oil or varnish, which also effectually excludes the air from contact with the window.

These precautions have reference chiefly to what is necessary in the daytime. At night, when the shutters are closed and the usual curtains drawn, there will be little difficulty in preserving a high uniform temperature in the room.

The door will require as much, even more, attention here than in the previous examples, as it may be oftener opened and by less careful attendants. A double door will seldom be had. A curtain-porch, made with thick calico, may be placed on either side of the door,—the inside is the best,—and the door re-hinged if needful to open to the passage, and the curtain drawn up by a string going through a loop, as described in a previous page.

The supply of air for the ventilation will mostly have to be taken from the windows or passage; by opening a hole in the floor, a communication can often be established between the joists and the external air. A ventilating-pipe, 3 or 4 inches in diameter, may either be raised from the ash-pit nearly to the ceiling and connected to a short pipe going through the furnace into the smoke-pipe, as before described; or the effete air may flow out into the chimney, through a perforation made in the chimney-breast or at an aperture made in one of the upper panes of the window: many ways will occur of doing this,—but one point with all of them must be considered essential. The air that is to spread through the room should always at its admission be made to impinge on one or more sides of the stove. Perkins' method (p. 232) may be imitated with advantage, when a common iron plate Dutch stove is the heat-generator. A cheap tube, for conducting the cold or effete air from one part to another, may be quickly made by pasting thick brown paper or canvass on laths to preserve its shape, or the coarsest sort of pasteboard may be used without laths to form a pipe.

By carefully pasting over air-crevices in windows and walls, placing a varnished paper or muslin screen before the glass, forming a curtain-porch to prevent the entrance of cold air on opening the door, and bringing in warm fresh air to supply what is required for ventilation, and impregnating it with vapour from a teakettle or pan set on the stove: a room that is capable of maintaining a high uniform temperature may be formed in the way described, at the cost of a sovereign. Poor invalids, who are told by their physician that removal to a warmer country would mitigate their pulmonary disease, in this room may, with a little care, procure all the ease that could be enjoyed without locomotion from the bland air of southern countries, and infinitely less subject to fluctuation than the most favoured climate in the world. And when their countrymen with more ample means, who seek soft medicinal air in the genial nooks of Italy or the south of France, are shrinking in spring from the clear sky, the dazzling heatless sun accompanied with black frost, or the mistral and clouds of dust, the poor invalids sitting in England beside their Dutch stoves will not only find

> "The unhealthful East
> That breathes the spleen, and searches every bone
> Of the infirm, is wholesome air to them,"

after flowing through their air-tubes and mingling with the balsamic exhalation from the kettle, but that the maintenance of this climate will not cost them one-third of the sum they formerly expended to warm the same apartments by means that only produced discomfort or engendered disease.

SICK ROOM. In the case of illness generally there is not perhaps a circumstance that a physician would consider of more aid to his remedies than a certain temperature and ventilation in the sick room. No forethought is shown in any house to have one bed-room at least fitted up so that at a moment's notice any required climate could be produced; and maintained night and day without inconvenience: yet there are few families in which an apartment of this description is not required many times in the year. Winter cough is much aggravated by a cold bed-room, and requires a temperature of 60°, which is not to be had at night in England more than 18 times in the year. The croup, according to Dr. Thomson, requires a temperature of 60°; hooping-cough, measles, and chicken-pox also 60°. Small pox and scarlet fever 60°, with copious ventilation every moment, to prevent their infection as well as to mitigate their symptoms; and perhaps a few degrees warmer, to prevent the patient being loaded with bed-clothes since no draughts would have to be guarded against. In gout, also, a soft uniform climate is most wished for; and to get rid of a cold, it would be pleasanter to endure confinement for a day or two in a room at 75° or 80°, than be obliged to lie in bed that time and eat water-gruel. The progress of fever and of a host of contagious diseases would be easier controlled and arrested in a room into which there was a constant flow of pure mild air regulated by the nature of the ailment, than in one subject to all the fluctuations of a variable climate, aggravated by the common method of "airing" and heating it. If there be any place more than another where an open fireplace is objectionable it is in a sick room.

A dependence on the mean averages of climate must always be very delusive to the sick. It is the sudden changes, and their duration within certain limits, that seem pernicious in many diseases. To the consumptive, for example, a fall of the thermometer from 80° to 67° would occasion comparatively little uneasiness, while a fall from 67° to 54° for a few days would not only aggravate their symptoms, but decide the crisis. The variations of temperature, if estimated by the total range of the thermometer in 24 hours, is greatest in summer. About London the variation of successive days at the same hour in the morning is greatest in the winter; in the afternoon, in summer.

The following table, shows the monthly average difference of temperature between day and night in the vicinity of London, during 1842, which year was remarkable for its general warmth; the whole month of December averaged 4° warmer nightly, and 4·5° warmer in the shade daily, than the same month in the preceding season. It will be seen that the average of August, the warmest month, is 10° below the temperature considered by Dr. Beddoes and others to be necessary for those affected with pulmonic disease; and according to the second table, one night during the same month it fell 20° under the limit: from all which it is evident that about London an artificial warm climate is required for the consumptive during night, throughout the year,—and in most other diseases, where the sick room requires a temperature of 60°.

	Night.	Shade.	Sun.
January . . .	30·2	35·9	40·8
February . . .	36·7	45·7	53·7
March . . .	40·2	51·1	61·3
April	40·0	54·8	77·3
May	47·8	62·7	81·7
June	55·5	73·0	99·5
July	56·9	71·7	93·3
August	60·2	74·9	100·5
September . . .	53·0	63·6	82·1
October . . .	39·5	50·5	61·5
November . . .	40·2	47·4	53·4
December . . .	40·9	48·8	54·4

The highest and lowest temperature each month is given in the next table.

		Lowest at Night °			Highest in Shade °			Highest in Sun. °
Jan.	24	25	Jan.	31	45	Jan.	27	56
Feb.	19	30	Feb.	11	52	Feb.	19	63
Mar.	7, 24	32	Mar.	29	58	Mar.	12	76
April	6	32	April	24	72	April	30	103
May	10	40	May	30	71	May	2	100
June	5	51	June	12	83	June	12	121
July	30	50	July	18	76	July	15	108
August	31	50	Aug.	19	87	Aug.	15	119
Sept.	20	47	Sept.	2	73	Sept.	2	109
Oct.	21	29	Oct.	9	59	Oct.	2	84
Nov.	17	34	Nov.	10	54	Nov.	1	68
Dec.	28	31	Dec.	13	56	Dec.	14	72

On an average of six years, there are about 80 nights' frost near London: the first frost is about the 15th of October, and the last about the 5th of May.

Medical writers on consumption have given much information concerning the temperature of different places resorted to by invalids, which has been collected and given by Sir James Clarke, in his interesting popular treatise on the Sanative Influence of Climate.

ESSAY XVII.

Not the least remarkable example of the power of habit, is its reconciling us to practices which, but for its influence, would be considered noxious and disgusting. We instinctively shun approach to the dirty, the squalid, and the diseased, nor use a garment that may have been worn by another; we open sewers for matters that offend the sight and smell, and contaminate the air; we carefully remove impurities from what we eat and drink, filter turbid water, and fastidiously avoid drinking from a cup that may have been pressed to the lips of a friend. On the other hand, we resort to places of assembly, and draw into our mouths air loaded with effluvia from the lungs and skin and clothing of every individual in the promiscuous crowd; — exhalations offensive to a certain extent from the most healthy individuals, but when rising from a living mass of skin and lung in all stages of evaporation, disease and putridity, and prevented by the walls and ceiling from escaping, they are when thus concentrated in the highest degree deleterious and loathsome.

This poisonous exhalation is one of the effects of the consumption of 14 ounces of charcoal that Dr. Liebig says is burned daily within the body. The share of impurity contributed by each living furnace has been variously estimated. From experiments with men of different stature, Dr. Menzies found that from 14 to 18 respirations were made in a minute; and others have found them vary from 13 to 22;—the average generally assumed is 20 respirations in a minute. The quantity of air drawn into the lungs at each inspiration varied from 40·7 to 46·7 cubic inches; and under all the circumstances, Menzies considered 720 cubic inches about the average quantity of air inhaled by a healthy man in a minute. A woman may inspire, on an average, about 500 cubic inches; a mean inspiration from a healthy pair of the species will not, probably, exceed 612 cubic inches in a minute.

The quantity, however, varies not only in the sexes but in the same individuals placed in different circumstances with regard to rest and motion to health and illness. During great exertion it will exceed the average, during rest, and in delicate and ailing persons it will fall under it; so that if 600 cubic inches be reckoned as expired in a minute by each individual in a mixed company, it will be a fair average allowance.*

The fresh air before it is taken into the lungs is composed of 23·2 per cent of oxygen, 75·5 of nitrogen, and about 1¼ per cent. of carbonic acid, and a variable quantity of vapour of water. After it has been expired from the lungs, in which it remains from 10 to 12 seconds, it contains a larger quantity of vapour, the same quantity of nitrogen, from 11 to 12 per cent. only of oxygen, and between 8 and 9 per cent. of carbonic acid; so that nearly a half of the oxygen or vital element of the air has been changed into carbonic acid. If atmospheric air contains 3·5 per cent. only of this gas, it is unfit to support animal life. Air, therefore, which has been expired from the lungs contains 2·4 times this quantity: so that a person who inhales 600 cubic inches a minute, renders 1,440 cubic inches unfit to be breathed again.

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* Dissertation on Respiration, p. 50. Trans. by Sugrue.

The amount of exhalation from the skin also varies in different individuals, and from the same person at different times—a hand emitted ⅕ grain in a minute, at another trial ½ grain, and in a third experiment it exhaled ¾ of a grain of vapour in a minute; which is 12, 30, or 45 grains a minute for the whole body.* If one of each sex be taken, the mean will be about 23 grains each in a minute. The skin surface of a man being about 15 square feet, 1·5 grains of vapour will be exhaled in a minute from each superficial foot of his body, or 3 grains from each cubic foot of his mass. Besides water, carbonic acid, acetic acid, phosphoric acid, muriate of soda, and a peculiar odorous matter are contained in the vapour emitted from the surface.

This copious cuticular discharge is seldom perceptible to the eye, although it is to the nose. Boerhaave made it apparent in the warm weather by immersing his hand in air cooled by ice, which then seemed to smoke like a boiling kettle; and he amused himself with the notion, that if winter's cold was produced in the midst of a crowded summer assembly, each individual seething in his own steam would appear like a heathen deity wrapped in his peculiar and appropriate cloud.

The emanation from lungs and skin is carried from the body by diluting it with atmospheric air, which at a certain temperature can hold in suspension a certain quantity of vapour, the amount of which is shown in the following table; the first column gives the temperature of the air, and the second column the number of grains of water a cubic foot of it will contain, in the form of vapour at that temperature:—

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* Cruikshanks. On Insensible Perspiration, p. 72.

Temperature.	Grs. of water in a cubic foot of air.	Temperature.	Grs. of water in a cubic foot of air.
32°	2·53	40°	3·23
33	2·63	41	3·37
34	2·71	42	3·50
35	2·80	43	3·63
36	2·89	44	3·76
37	2·97	45	3·89
38	3·06	46	4·02
39	3·15	47	4·15
48	4·27	70	8·39
49	4·40	71	8·65
50	4·53	72	8·92
51	4·68	73	9·19
52	4·83	74	9·48
53	5·03	75	9·78
54	5·17	76	10·10
55	5·34	77	10·38
56	5·51	78	10·69
57	5·67	79	11·01
58	5·86	80	11·33
59	6·04	81	11·66
60	6·22	82	12·05
61	6·39	83	12·35
62	6·57	84	12·71
63	6·79	85	13·08
64	7·01	86	13·45
65	7·23	87	13·87
66	7·44	88	14·23
67	7·66	89	14·61
68	7·89	90	15·00 *
69	8·13		

According to the table a cubic foot of air at the freezing point can retain 2·53 grains of water only; if therefore it contain 1 grain only, then each cubic foot

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* Daniel. Meteorological Essays, p. 158.

will absorb or carry off 1·53 grains of vapour from a moist surface which may be the insensible perspiration from the surface of the body. If this air be heated to 60°, a cubic foot of it will carry off 5·22 grains of moisture from the skin; for it is seen from the table that air at 60° can suspend 6·22 grains of water. To carry off 23 grains of insensible perspiration per minute will therefore require about 15 cubic feet of the colder air, and about 4·4 cubic feet of the warmer air. If less than this be supplied, the moisture will accumulate on the skin, and the air of the room become saturated with vapour.

If the average temperature of the room be taken at 64° with the dew point about 50° or with 4·53 grains of water in each cubic foot, then about 9·25 cubic feet of air will be required per minute for the insensible perspiration, and in addition 1 cubic foot nearly for the excess of moisture from the lungs not carried off by 1,440 cubic inches allowed for the dilution of the carbonic acid gas; so that about 10·25 cubic feet of pure air a minute must be allowed to ventilate each person.

But if a greater proportion of moisture is added artificially to the air, this quantity must be encreased. In every case ventilation should be regulated with reference to the hygrometric condition of the warmed air.

Dr. Reid states, that he never gave less than 30 cubic feet of air a minute to each member of the House of Commons when the room was crowded, and on one occasion he introduced for weeks successively 60 cubic feet a minute to each member, and that to give the necessary moisture, 5,000 square feet of moist evaporating surface was exposed to the air;* and subsequently, as stated in a previous Essay, the air was made to flow through jets of water; and this saturation probably it was that rendered this quantity of ventilation necessary and pleasant.

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* Reports of the British Association, vol. vii. p. 132.

In whatever way the air of a room is heated, it is cooled by coming in contact with the glass of the windows, by the walls, ceiling and floor absorbing the heat, and by cold air entering at doors and windows, and the crevices round them, and sometimes by the chimney when it is left open.

Each square foot of glass in a window will cool about 1 cubic foot of air as many degrees per minute as the temperature of the room exceeds the temperature of the external air. If a window has 5 square feet of glass, and the temperature out of doors be 32° and the room 60°, then 5 cubic feet of air will be cooled 28° in a minute. Of the quantity of cold air admitted at the crevices round the window-sashes and round the door, no definite estimate can be given: it depends on the position of the window above the floor, on its fitting, on the difference of temperature between the room and the air outside on the force of the wind, and other causes. If three times the width of the sash added to twice its height be multiplied by ·3 it will give about the number of cubic feet of air cooled from this cause. The crevices round the sashes of a window 4 feet wide and 8 feet high, will cool about 8·5 cubic feet in a minute.

Twice the width added to the height of a door multiplied by ·26, will give the cubic feet of air cooled per minute for that opening when well made: a door 3 feet wide and 7 feet high will cool about 5·2 feet in a minute.

The absorption and radiation of heat from every 200 square feet of the wall, ceiling, and floor, may be taken on an average as equal to cooling 1 cubic foot of air per minute as many degrees as the internal is warmer than the external air.

When wax or tallow lights are burned, about ·25 cubic foot a minute must be allowed for each.

With the air at 64° and dew point at 50°, every inhabited apartment must therefore have the following allowance of heated air per minute:—

	Cubic feet.
For the supply to the lungs .	·83
To carry off insensible perspiration	10·2
For each common sized candle .	·25
Square foot of glass in window .	1·0
Each window, for chink winds .	8·5
Each door about ditto . .	5·2
Each 200 square feet of wall, ceiling, floor, exclusive of windows	1·

Suppose a room 30 feet long, 20 feet wide, and 16 feet high, with 3 windows 8 feet by 4 feet, and 2 doors 3 feet by 7 feet, and containing 20 persons;

	Cubic feet.
20 persons will require for lungs and skin	16
3 windows, 96 square feet of glass .	96
—— for crevice winds	25·5
2 doors for ditto	10·4
2,800 square feet, wall, ceiling, floor .	14
	161·9,

or heat equivalent to raising 161·9 cubic feet of air per minute. To this must be added ¼ cubic foot per minute for each light: should the air contain more than 4·53 grains of vapour, the quantity for ventilation must be increased. If, for example, the air at 64° held six grains of water in suspension, then 23·2 cubic feet must be allowed to carry off the personal exhalations, instead of 16 feet.

In fixing the quantity of heating-surface to produce this effect, some points have to be considered. The wind, for instance, greatly accelerates the cooling of the walls and windows in any state of the air; the air being moister at one period than another, much increases its power to carry off heat, and there are great changes of temperature. So that if a steam pipe or a hot surface was sufficient to heat a certain sized building, when the air was at the freezing point, and calm and dry, it would be inadequate to heat the same building when the air was at the same temperature but windy, or when it was moister, or when it fell below the freezing point.

As the hot water, steam, or hot air apparatus cannot be enlarged, nor its temperature raised beyond a certain point, and as it must be proportioned to meet the greatest degree of cold that is likely to happen, in practice, the usual way to make an allowance for these contingencies is to calculate the quantity of surface that would be required to heat the building, if the outside air were at the lowest degree to which it had ever fallen in the place where the apparatus is erected.

Mr. Howard says, that a night on which Fahrenheit's thermometer remains for some hours below zero is a rare occurrence in this climate, and probably not above five of them fall in a century;* and therefore the apparatus, whatever be its form, may be proportioned to produce a given effect at this low temperature. The opposite limit may be taken from the table given in the preceding Essay (p. 311). The greatest differences of temperature are during night; but it is more difficult to keep an inhabited room warm in the day-time than at night, from the heat lost by the glass and air-crevices in windows being saved mostly after sunset, by the use of shutters and curtains.

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* The Frost of 1794-1795 lasted 44 days, one whole day's remission excepted, immediately before which the thermometer fell to 2° below zero. 1796-1797 temperature fell to 6·5, and continued below zero for several hours. Lowest temperature of air, 9th Feb. 1816, was 5° below zero. At eight o'clock in the morning the temperature began to rise, at noon 25° was pleasant by contrast to the feeling; and it was easy to keep warm by walking without an upper coat. Even at zero, however, the first impression of the air on the skin was not disagreeable, the dryness and stillness greatly tending to prevent that sudden abstraction of heat which is felt in moist and quick flowing air.—Climate of London, vol. ii. p. 290.

In estimating the quantity of steam, or hot water-pipe that should be placed in the room described, to allow 161·9 feet to be heated in a minute; the statement would be thus: external air at zero, temperature of room 64°, pipe-surface 200°; then by rule (p. 279), $125 \times 64 \div 136 \times 157{\cdot}4 \div 222 = 41{\cdot}1$ feet of 4-inch pipe would be required.

If the cubic content of the room, 9,600 feet, be divided by 209,—the number opposite a similar room in the table (at p. 258),—the quantity of surface will be found 45 square feet nearly; so that, if in the estimate of air for ventilation, any allowance had been made for the lights, the two methods would have almost coincided. The number from the table is, however, the one most to be depended on.

The quantity of air to be heated being determined, the size of the aperture for the egress of the vitiated air may be found in the following way:—When air at 32° is heated to 680°, it is increased in size as under:—

Temperature.	Bulk.
° 32	1·000
212	1·3750
302	1·5576
392	1·7389
482	1·9189
572	2·0976
680	2·3125*

between the freezing and boiling points it expands $\frac{1}{480}$th part of its bulk for each degree it is heated. If, therefore, the square root of the difference expressed in feet between the linear expansion of a column of air at 32°, and a column with the same base, when heated, be multiplied by 4, and the product multiplied by 2, and that product by ·7, the result will give the velocity nearly in feet with which the heated air will flow through an opening into the colder air.*

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* Annals of Phil. vol. xiii. p. 116.

In a room 16 feet between the floor and ceiling, when its temperature is 64°, and the air outside is 32°, the warm air will flow through an aperture in the ceiling with a velocity of 7·8 feet in a second; if the number of cubic feet of air required for ventilation in a second be divided by the velocity thus found, it will give the area in square feet of the aperture required. In the above example, as 161·9 cubic feet is to be removed in a minute, the ventilator will require to have an area of about 43·2 square inches. This also

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* The velocities of ascending currents of air, as determined from calculation, exhibit extraordinary variations. In the same room and furnace the velocity per second of heated air through a ventilator, and the draught of a furnace, is given by various writers, as under:—

	Ventilation per sec.	Draught of furnace per sec.
Montgolfier	8·32	13·91
Sylvester. Rees' Cyclo. .	0·78	1·94
Gilbert	7·88	225·67
Sylvester. Ann. Phil. . .	1·61	7·73
Tredgold	4·80	9·51†

If we were to judge from the practical results which have hitherto been obtained from the enquiry, it would appear that all calculations on the subject are nugatory.—Theory and Practice of Warming Buildings, p. 172.

The difference between the theoretical and actual velocity of air rising through the chimney, 45 feet high, of a stove, is thus exhibited by Dr. Ure:—

By theory.	Experimental.	Mean temp. of chimney.
Feet.	Feet.	°
26·4	5·0	190
29·4	5·76	214
34·5	6·3	270

In none of the experiments did the velocity exceed 12 feet per second when the difference of temperature was more than 410°.—Arch. Mag. iv. p. 168.

may be the size of the opening to admit the cold air; but in practice it is made considerably larger, to diminish the velocity of the air at entering the room.

The size of the ventilator will depend on whether the heating-surfaces are placed in the area heated, or the warmed air flows into the room. If the heating-surfaces are placed in the room, that quantity only of air necessary to carry off the expired and exhaled gaseous matters will have to be removed; which, in the case above, is 16 cubic feet a minute for each person; but if warm air is introduced, then the ventilator must carry off in the same time 161·9 cubic feet lessened by the allowance of 16 cubic feet for respiration, when the quantity admitted for other losses of heat exceeds that quantity. It is also obvious, the ventilator should have the dimension that will allow passage for the necessary quantity of air for ventilation when it is nearly saturated.

[illegible]

FUEL.—"One may observe," says Fuller, in 1661, "a threefold difference in our English coal. Sea-coal brought from Newcastle, land-coal at Mendip and Bedworth, and parted into other counties, and what we may call river or fresh-water coal digged out in Shropshire at such a distance from Severne that they are easily parted by boat into other shires. I am sorry to hear that those black Indies, both in quantity and quality, fall short of their former fruitfulness, and I wish they may recover their lost credit. Oh! if this coal could be so charcked as to make iron melt out of the stone, as it maketh it in the smithies forge to be wrought into bars;—but Rome was not built in one day, and a new world of experiment is left to the discovery of posterity."*

Since Fuller's time the world of experiment has been busily explored. Coals now are charked, and melt iron-stone, and are preferred to wood for domestic purposes; and instead of 200,000 chaldrons being imported into London, (which was the amount in his time,) last year 9,691 ships brought into the port of London upwards of 2,754,719 tons, and without a fear of either the quantity or quality of the "black Indies," now called "black diamonds," falling off for many centuries. Mr. Taylor, an experienced coal-viewer, calculates the annual quantity of coals raised at 15½ millions of tons, and says the mines of Durham and Northumberland will supply this demand for 1,700 years to come. In addition, Dr. Buckland considers the mines in South Wales alone enough for 2,000 years' consumption;* and when these are worked out, other extensive mines may be opened in different parts of England and in Scotland.

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* Worthies, vol. ii. p. 97.

According to Mr. M'Culloch, there are upwards of seventy varieties of coal brought to London, forty-five of which are sent from Newcastle; but many of them differ by almost imperceptible degrees, and can only be distinguished by those thoroughly conversant in the trade. Dr. Thomson arranges them in four divisions: — *Caking Coal,* or "Newcastle coal," is found in Northumberland, Durham, in Cumberland, at Whitehaven, at Wigan, in some parts of Derbyshire, at Swansea and Leitrim, and at Glasgow and other places in Scotland, and contains a large proportion of bitumen. *Splint coal,* or stone coal, found near Glasgow, in Ayreshire, and in some places in England; it contains little bitumen, much earthy matter and ashes. *Cherry coal* is got from the upper beds of the Glasgow coal-fields, in Fifeshire, near Edinburgh, and in Staffordshire. *Cannel coal,* called in Scotland Parrot coal, is found in comparatively small quantities. These different kinds are sometimes all met with in the same mine; and there are many varieties, partaking of the nature of all three.

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* Ency. Brit. vol. vii. p. 8.

Analysis resolves coal into several substances, all of which are gasses, except carbon, which is the principal ingredient in every variety. Their chemical composition is thus stated by Dr. Thomson * :—

	Carbon.	Hydrogen	Nitrogen.	Oxygen.
Splint coal . .	75·00	6·25	6·25	12·50
Caking coal . .	75·28	4·18	15·96	4·58
Cherry coal . .	74·45	12·40	10·22	2·93
Cannel coal . .	64·72	21·56	13·72	—

The following table, by Mr. Mushet, shows the amount of charcoal ashes and volatile products procurable from equal weights of different kinds of wood and coal made thoroughly dry :—

Woods.	Volatile prod.	Charcoal.	Ashes.
Lignum vitæ .	27·643	26·857	0·500
Mahogany . .	73·528	25·492	0·980
Laburnum . .	74·234	24·586	1·180
Chestnut . .	76·304	23·280	0·416
Oak	76·895	22·682	0·428
American Black Beech . .	77·512	21·445	1·033
Walnut . . .	78·521	20·663	0·816
Holly . . .	78·920	19·918	1·162
Beech . . .	79·014	19·941	0·955
Sycamore . .	79·200	19·734	1·066
Elm	79·655	19·574	0·761
Norway Pine .	80·441	19·204	0·356
Sallow . . .	80·371	18·497	1·132
Ash	81·260	17·972	0·768
Birch	80·717	17·491	1·792
Scotch Pine .	83·095	16·456	0·449

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* Ann. of Philosophy, vol. xiii. p. 94.

Coal.	Volatile product.	Charcoal.	Ashes.	Sp. grav.
Kilkenny coal .	4·25	92·87	2·87	1·60
Welsh stone, do.	8·00	89·70	2·30	1·37
Welsh furnace, do.	8·50	88·06	3·43	1·33
Welsh slaty, do.	9·10	84·17	6·72	1·49
Corgee coal, Irish	9·10	87·49	3·49	1·40
Queen's County, do. .	10·30	86·56	3·14	1·40
Kilkenny slaty, do.	13·00	80·47	6·52	1·44
Bonlavoneen, do.	13·80	82·96	3·24	1·43
Stone Wood, Giant's Causeway . . .	33·37	54·69	11·93	1·15
Butterly furnace coal . . .	42·83	52·88	4·29	1·26
Alfreton, do. .	45·50	52·45	2·04	1·23
Derbyshire cannel	47·00	48·36	4·61	1·28
Scotch cannel .	56·57	39·43	4·00	—

When the coals are carbonized in close vessels, Dr. Thomson found that in 1,000 lbs. of coal there were, in

		Per cent. of earthy matter.
Splint coal, 647 lbs. of coke, containing		9·5
Cherry coal, 522 lbs.	—	10·
Caking coal, 774 lbs.	—	1·5*

The heating *effect* of different kinds of wood is given by Count Rumford. The woods, with one exception, were selected pieces, made quite dry by heating in a stove. The figures show the weight in pounds avoirdupois of each wood required to melt 62½ lbs. of ice :—

	lbs.
Lime-tree . . .	1·35
Ditto, highly dried . .	1·18
Beech	1·38

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* Ann. of Phil. vol. xiii. p. 94.

	lbs.
Elm	1·54
Ash	1·53
Maple, highly dried	1·30
Service-tree, highly dried	1·31
Cherry-tree	1·40
Fir	1·54
Poplar	1·35
Hornbeam	1·47
Oak, with 19 per cent. water, combustion not perfect	1·78
Oak, common fire-wood in chips	1·83

In Mr. Kirwan's comparison of different kinds of fuel, the effect of coke is beneath the average. The same quantity of heat, according to his table, being produced by—

lbs.		Measures.
403 of coke	or by	17 of coke.
600 pit-coal	,,	10 pit coal.
600 charcoal	,,	40 charcoal.
1,089 oak	,,	33 oak.*

M. Peclet's averages of effect from the same weight of each substance, are as under,

Charcoal	7300
Bituminous coal	6000
Coke, giving 0·15 ashes	6500
Good turf	3000
Turf coke, ·18 ashes	6400
Wood, quite dry	3500
Wood, as it commonly occurs, with 25 per cent. water	2600
Tallow	7912
White wax	9990 †

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* Rumford. Essays, vol. ii. p. 184.

† Donovan. Dom. Economy, p. 242.

Mr. Marcus Bull took great pains to determine the economical effect of many varieties of American firewood: some of his results are given in the table beneath.* The first column notes the specific gravity of the wood when carefully freed from moisture by stove drying; the second, the weight of charcoal contained in 100 parts by weight of wood; the third column the specific gravity of the charcoal; and the fourth column the *effect* of the *dry wood* in heating a room, or the number of hours the same weight of each kind of wood that was consumed maintained the same room at a certain temperature.

Wood.	Sp. gy. of dry wood.	Charcoal.	Sp. gy. of charcoal.	H.	M.
White ash . . .	·772	25·74	·547	6	40
Apple tree . . .	·697	25·	·445	6	40
White beech . .	·724	19·62	·518	6	
White elm . . .	·580	24·85	·357	6	40
Shell bark hickory	1·000	26·22	·625	6	40
Welch hazel . .	·784	21·40	·368	6	10
American hornbeam	·720	19·	·455	6	
Hard maple . . .	·644	21·43	·431	6	10
White oak . . .	·853	21·62	·401	6	20
Red oak	·728	22·43	·400	6	20
Yellow pine, (soft)	·551	23·75	·333	6	30
Pitch pine . . .	·426	26·76	·298	6	40
Lombardy poplar .	·397	25·	·245	6	40
Wild service . .	·887	22·62	·594	6	20
Sycamore . . .	·535	23·60	·374	6	30
Black walnut . .	·681	22·56	·418	6	20
Stove-dry ebony .	1·090	33·82	·888		
Do., live oak . .	·942	32·43	·591		
Tortoise-shell wood	1·212	30·31	·866		
Turkey box . .	·933	27·24	·622		

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* Experiments to determine the Comparative value of Fuel, p. 66.

From this table, it is probable that equal weights of any kind of dry wood submitted to perfect combustion would produce nearly the same quantity of heat: a pound of pitch pine will be as effective in a stove as a pound of oak.

Mr. Bull also determined the effect of some kinds of American and English coal, when burned in the same apparatus. An equal weight of each coal kept a room at the same temperature for the time in hours and minutes noted in the second column:—

	Specific gravity.	H.	M.
Lehigh coal	1·494	13	10
Lacawaxen coal	1·400	13	10
Rhode Island coal	1·438	9	20
Schuylkill coal	1·453	13	40
Susquehanna coal	1·373	13	10
Swalara coal	1·459	11	20
Worcester coal	2·104	7	50
Karthans coal	1·263	9	20
Richmond coal	1·246	9	20
Stony Creek coal	1·396	9	50
Cannel coal, English . . .	1·240	10	30
Liverpool coal, do.	1·331	9	10
Newcastle coal, do.	1·204	9	20
Scotch coal	1·140	9	30
Hickory charcoal	·625	15	
Maple charcoal	·431	15	
Oak charcoal	·401	15	
Pine charcoal	·285	15	
Coal	·557	12	50
Composition fuel—2 parts Lehigh coal, 1 part charcoal, and 1 part clay, by weight .		13	2

A similar uniformity of heating effect is observed in English coal as in the woods. The same weight of Newcastle, Liverpool, and Scotch coal produces the same quantity of heat when properly consumed in the same stove. And the same weight of charcoal of any wood may also be considered to generate the same quantity of heat in a stove.

The effect of the composition fuel seems however under-rated. As a fuel, it is described by Mr. Bull to be very clean and beautiful in its appearance; and its superior cleanliness to be in consequence of the ashes being retained by the clay; and the balls were found to retain their shape after being deprived of their combustible materials, and which presented during combustion uniform luminous faces. No difficulty was found in equaling or consuming the combustible material in the balls.

The weight of moisture absorbed from the atmosphere by woods which had been previously made perfectly dry was 10 per cent. in 48 different woods, by free exposure under cover, and 8 per cent. in the driest states of the atmosphere. Charcoal 8 per cent.

The quantity of moisture absorbed by the woods individually was not found to diminish with their increase in density. Green woods in drying uniformly lost less in weight in proportion to their greater density. Taken green, and made absolutely dry—

Hickory wood lost .	37·5	per cent.
White oak . .	41·	„
Soft maple . .	48·	„

If the mean quantity of moisture in woods when green be taken at 42 per cent. in burning wet wood, it is obvious, in every 100lbs. of fuel 42lbs of aqueous vapour must be expelled from the wood; and as the capacity of water for absorbing heat is nearly as 4 to 1 of air, and probably greater during its conversion into vapour, the loss of heat from this cause is very great in open fireplaces or in furnaces.

The average weight of moisture in different woods which have been weather-seasoned from 8 to 12 months will be about 25 per cent.; hence the propriety of keeping wood under cover where practicable.

It will be easy from the tables to select that species of fuel most suitable to the apparatus in which it is to be burnt. In all kinds of stoves, for instance, where the smoke is conducted through horizontal pipes, or pipes with elbows, or long flues, charcoal or coke will in general be found the most desirable fuel. The accumulation of soot in the smoke-passages will be very trifling, and the surfaces being thus kept clean the heating effect will be considerably greater. The next best fuel for stoves is those varieties of coal in which the volatile products bear a small proportion to the charcoal product.

Some of the Irish and Welsh coal are nearly as good as charcoal for a stove; but they are more difficult to manage, and require, like coke, to be used in small pieces when the fuel-chamber of the stove is small. Wood is generally burned in stoves abroad; it is scarce, and on that account better managed than with us; but it soon clogs the smoke-passages.

Damp wood does not appear to be so uneconomical when used in a stove with long smoke-pipes, or with flues, as when burned to evaporate water, or in an open fire; for the vapour raised from the water is condensed in the pipe or flue, and a portion of its heat is by that means made productive. In Sweden, birch is reckoned the best fire-wood, from burning without throwing out sparks. Beech wood fuel was in former times reckoned the best in England.

In rooms heated by any kind of stoves, great attention should be paid to make the chimney flue into which the pipe of the stove is inserted air-tight with regard to the room, except through the stove, and to diminish the diameter of the chimney-pot to the area of the pipe of the stove. In upper stories and garrets, it is a good plan, where the flue is wide and straight, to carry up the stove-pipe through the flue, and terminate it at the chimney-pot, and make the space round it air-proof to the room as well as to the atmosphere. By this means, a higher temperature is preserved in the ascending heavy carbonic vapour, and when coke or charcoal is burned, there is less danger of its being cooled and descending through the stove into the room; which happens sometimes where the flue is wide, when the fire in the stove is extinguished. A roofed cowl, or one with some contrivance to prevent the drifting of rain into the pot, is also necessary, especially when contracted to a small area.

If this smoke pipe were carried from a bed-room over a drawing-room for instance, that it was wished to ventilate, a pipe from the room introduced into the space between the flue and the pipe, and a communication opened at the top to the atmosphere, the effete air would be drawn in a steady current, from the drawing-room, and emitted at the chimney-top. In this way a powerful and convenient ventilator might be formed in every stack of chimneys to every room connected with it.

It has been noticed in describing many of the contrivances for heating, that they were more or less valued as cures for smokey chimneys, which, in ancient houses, were almost always occasioned by the faulty construction of the hearth recess—the mantel was too high from the hearth, or the chimney leading from it was too wide, faults also found in the greater number of modern houses; the certain remedy is to reduce the opening of the fireplace in all its dimensions, and particularly in the height of the mantel, according to the rules given by Count Rumford, described at page 121.

Where the rooms are very small, chimneys often smoke, even when heated by a grate on the best common construction. If the smoke comes into the room when the doors and windows are closed, and flows freely when they are opened, then the descent of the smoke is caused by a want of air to supply the current up the chimney. To contract the throat of the chimney, or place a narrow-mouthed pot on the ajutage at the chimney-top will sometimes cure this defect, when as much air finds its way through chinks as is equal to the quantity flowing through the contracted opening,—but the improvement is only partial. The throat should be formed of the proper size and shape, (see page 121,) and air should be admitted to the room by a separate channel. There are many well-known ways of doing this: by a moveable pane, a *was-es-dat,* channels or pipes from the outside, or openings made over the door (page 71): but the neatest and best method is to introduce the necessary quantity of fresh air through the heating cavity of a warm air grate, the apertures in which may be double the area of the passage for the smoke at the throat; and to divide the current, the opening may be covered with wire cloth.

Chimneys sometimes continue to smoke after air-channels have been formed, especially when the fire is large and burns vividly. In this case the air is not supplied in sufficient quantity, and there is a downward current formed in the chimney to supply the deficiency, and the smoke impeded in its ascent comes into the room. It is obvious the remedy is to increase the size of the air-ducts.

To the same want of air it is owing that when a door is hastily shut or "slammed," smoke and dust are drawn downward from the chimney. This seldom happens where the exterior air has free ingress into the room, through proper-sized openings; it often occurs when the room is heated by a Dutch stove, and then occasions more annoyance than with an open fire, as the room cannot be so quickly cleared of it. An air-stove with large air openings, which have a communication with the atmosphere is the proper remedy.

When there is a large fire in an adjoining room, or in a room opening from the same passage or staircase, it will draw the air, from the room or passage connected with it, particularly if they are small. Here the remedy must be applied to the large fire: a sufficient quantity of air to supply the current up its chimney must be furnished from some other independent source and conducted into the room itself, or into the passage, or space which connects the two rooms.

In many houses in which there are what are called thorough draughts, such as the front and back doors being placed in opposite walls, in some winds the flow of air from the passage into the rooms is obstructed, a partial rarefaction is produced, and the smoke descends into all the rooms connected with the passage. In this case a porch must be added to one of the doors, that to the leeward is the most proper. This is a troublesome defect, as its removal depends on the proper management of the doors in stormy weather. —The chimneys of houses situated on the sides of hills smoke in certain winds, particularly when they blow down the slope on which the house stands. Here all the chimneys are more or less affected by the downward current forming a partial vacuum in the apartments. Apertures opening towards the wind, are the only effectual remedies.

Chimney-pots, of many forms, are applied to the smoke ajutage at the chimney-top. All are more or less corrections of errors in the formation of the chimney and hearth recess, and show want of skill in the builder. They are often useful, to diminish the size of the opening and prevent the entrance of the air into the flue, which lowers the buoyancy of the ascending smoke. Pots also regulate the quantity of air admitted to the fireplace; which, however, is better done by contracting the throat. In winds which, by their superior velocity, impede the rising current, a turn-cap or cowl, with its opening turning from the wind, forms a passage without obstruction to the leeward. Some cowls are formed with an inclined plane around their ajutage, which, deflecting the wind, at the orifice, assists the rise and escape of the smoke.

It is sometimes necessary to cover the orifice to prevent winds, to which by some local object an inclined direction has been given, from blowing down the chimney. The varieties of this contrivance are numerous. The common cottage cap, formed by a piece of stone or metal placed inclined to the wind, and closing up the top and windward side and leaving the other faces open, is the best.

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UNIV. C
FEB 13 1912

LONDON:
WILLIAM STEVENS, PRINTER, BELL YARD,
TEMPLE BAR.